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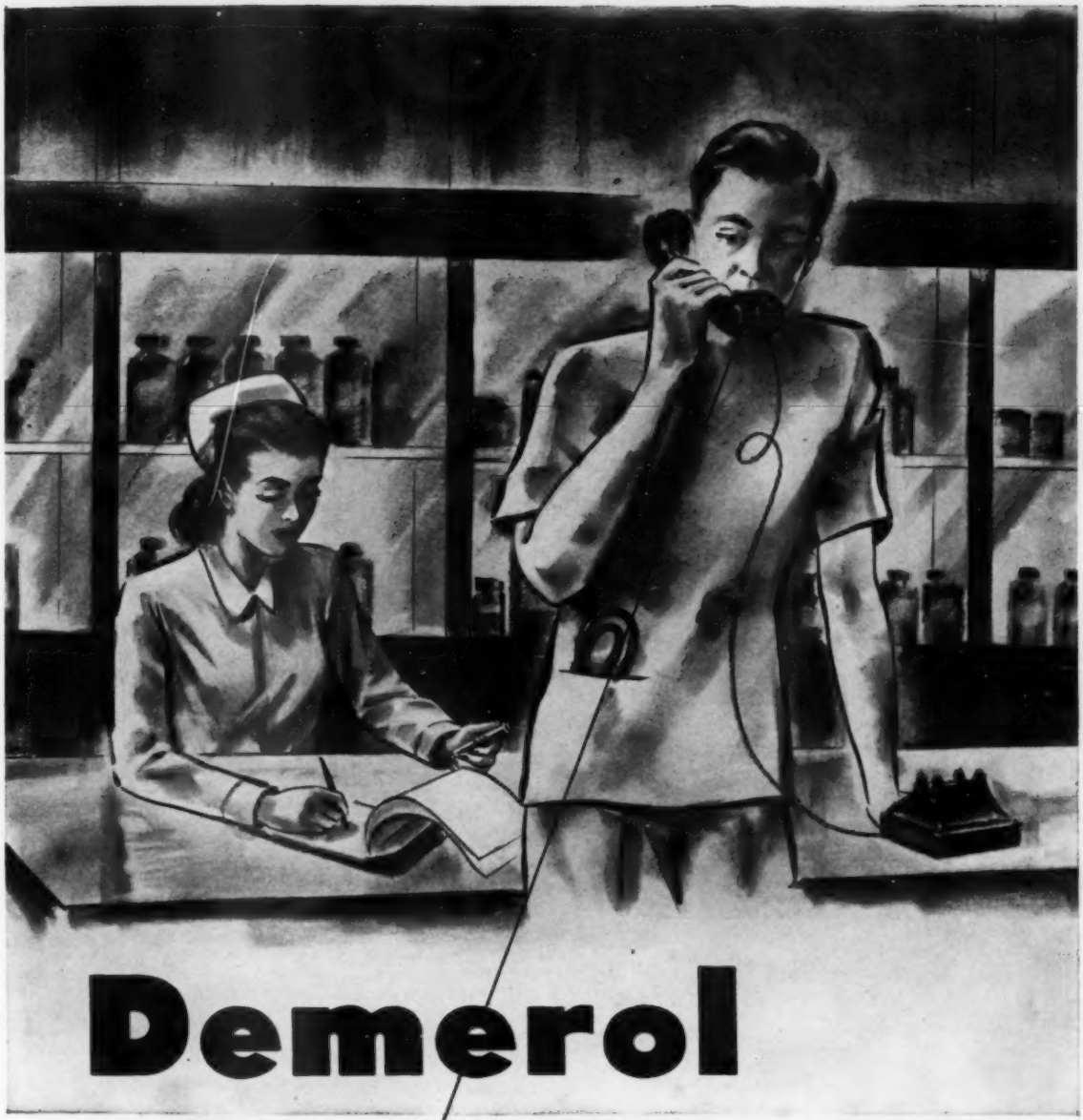

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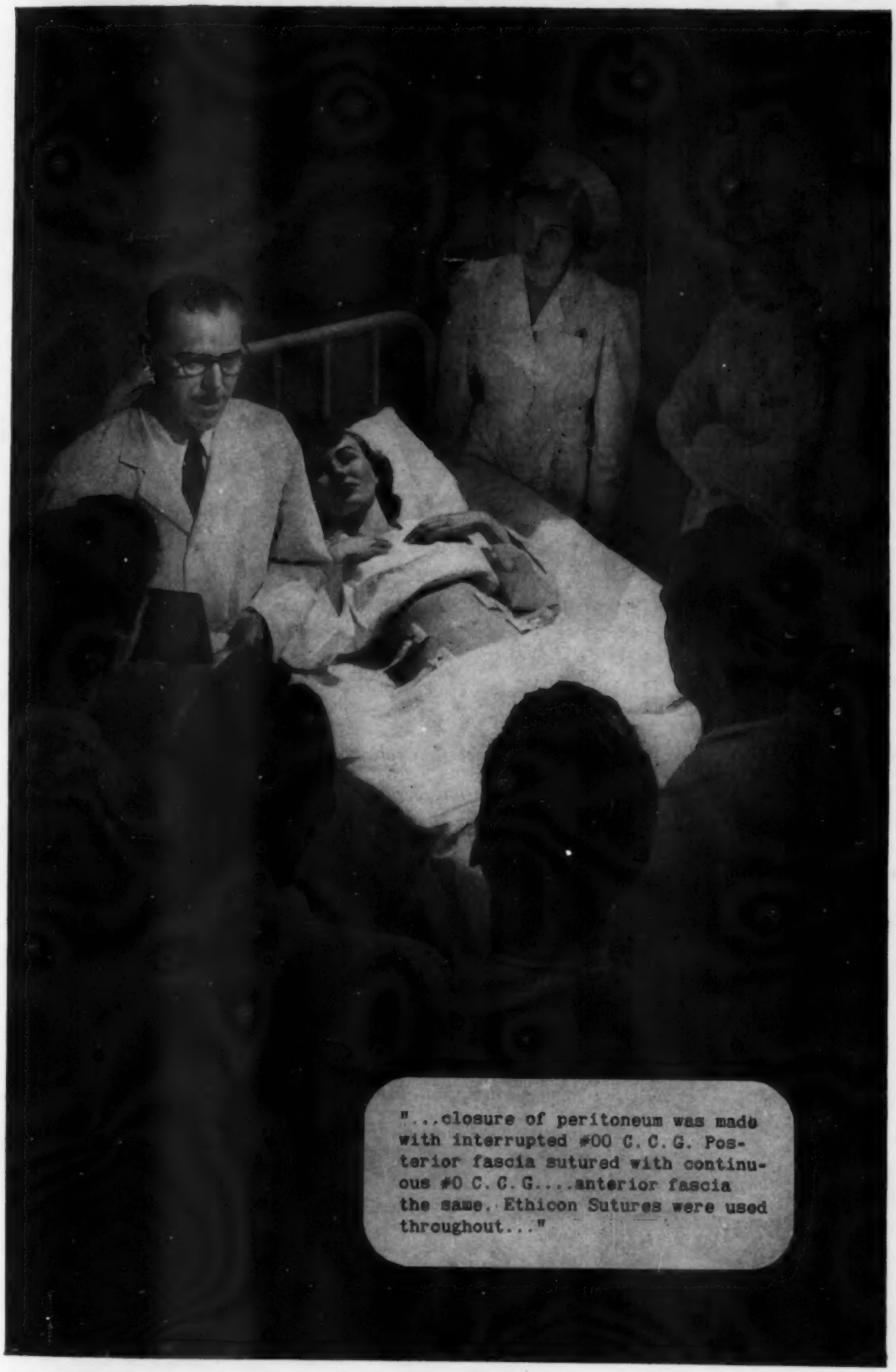
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ARCHIVES OF SURGERY

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COPYRIGHT, 1948, BY THE AMERICAN MEDICAL ASSOCIATION

CAUSATION AND TREATMENT OF PAINFUL STIFF SHOULDER

Subdeltoid Bursitis, Periarthritis, Tendinitis and Adhesive Capsulitis

HENRY W. MEYERDING, M.D.
AND
JOHN C. IVINS, M.D.
ROCHESTER, MINN.

MUCH of the confusion that confronts the medical profession in dealing with disabling conditions of the shoulder attended with pain and stiffness is the result of the terminology employed. The following diagnoses are commonly used without regard for the actual pathologic changes present: subdeltoid bursitis (1867 and 1869), subacromial bursitis or adherent subacromial bursitis, calcified bursitis, frozen shoulder, arthritis, Duplay's disease (1872), periarthritis, scapulohumeral arthritis, periarticular adhesions, bicipital tenosynovitis, peritendinitis, tendinitis of the short rotators, adhesive capsulitis, osteoporosis, neuritis, fibrositis, myositis, post-traumatic strains and sprains, musculotendinous cuff tears, Codman's[1] "rim rents" (first mentioned in 1902) and many others. Furthermore, painful stiff shoulders may result from trauma with or without fracture, infections, such as osteomyelitis, or septic joints, from mastectomy or some other regional surgical procedure, from primary or secondary tumors and from many other skeletal lesions. Osteoporosis may accompany the lesion. All these conditions may be attended with a period of disuse, during which the patient's shoulder is more or less immobilized in adduction because of pain or fear of pain. Following such limitation of motion and pain, the shoulder may become stiff or "frozen," and disability results. The surgeon should try to ascertain the underlying causative and pathologic factors, in order better to carry out rational treatment.

Unquestionably trauma plays a vital role in the pathogenesis. The anatomic structure of the shoulder permits repeated attritional dam-

---

Dr. Meyerding is from the Section on Orthopedic Surgery, Mayo Clinic, and Dr. Ivins is a Fellow in Orthopedic Surgery, Mayo Foundation.

Read at the fifty-fifth annual meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 4 to 6, 1947.

1. Codman, E. A.: The Shoulder: Rupture of the Supraspinatus Tendon and Other Lesions in or About the Subacromial Bursa, Boston, Thomas Todd Company, 1934.

age to the musculotendinous cuff, especially during certain types of work which require repeated abduction and rotation. It is at the site of the cuff or conjoined tendon of the teres minor, supraspinatus, infraspinatus and subscapularis muscles that minute frictional injuries, rupture and calcification occur. The formation of calcified masses at the site of insertion of these rotator tendons has been observed. The bursa is so intimately fused with the cuff that, as the calcified mass en-

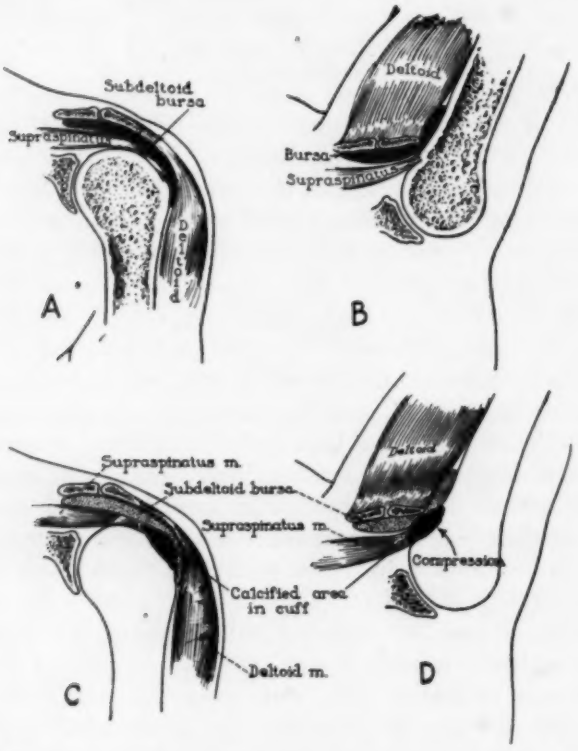

Fig. 1.—The structures of the shoulder: *A*, in adduction. *B*, in abduction. *C*, in adduction with a calcified mass in the rotator cuff. *D*, in abduction showing compression of the calcified mass and bursa. This illustrates how the calcified mass may be ruptured into the bursa.

larges, it bulges into the bursa. In abduction rotary motion, compression against the acromium may cause rupture into the bursa (fig. 1), and in such cases aspiration may yield a milky fluid. Thus, calcium apparently forms beneath the subdeltoid bursa in the region of scarring in the rotator cuff. It is located near the greater tuberosity and between the bursal and articular spaces. This devitalized avascular repeatedly traumatized scar provides the local degenerative condition necessary for pathologic calcification; it accounts for the frequency

with which painful stiff shoulders are encountered in patients after 40 years of age (76 per cent of our series of 150 cases).

It is evident from the foregoing description that these lesions which start in the rotator cuff are initially extra-articular and extrabursal, but may produce secondary periarticular and intra-articular effects. While these calcified masses may be absorbed spontaneously in some cases, they remain for years, in spite of various forms of treatment. We believe that a diagnosis of calcified subdeltoid or acromial bursitis should be avoided; bursitis may be present with pain and stiffness, but the calcification is not in the bursa.

The actual cause of the stiffness, or "frozen shoulder," is the subject of considerable controversy. There are, however, three locations in which pathologic conditions have been proved, namely, (1) adhesions in the synovial reflection at the anatomic neck of the humerus, (2) adhesions in the synovial pouch extending along the biceps tendon and (3) adhesions within the bursa. McLaughlin[2] has called attention to these changes and has added that it seems reasonably certain that fibrotic or cicatricial change in the intrinsic tissues of the cuff or in the interstitial tissues of the periarticular musculature also may play a part in producing the restriction of active motion. The weakness noted following release of these adhesions is most likely due in some measure to muscular atrophy resulting from disuse.

Occasionally a patient with coronary occlusive disease or angina pectoris has a painful stiff shoulder. There is no rational reason why cardiac disease, per se, should cause a stiff shoulder, and doubtless it is the fear of pain, which is initiated by exertion, that in the early stages prevents the patient from moving the arm and shoulder; subsequently the stiffness resulting from adhesions and atrophy is in turn the result of prolonged immobility. Further study of this subject is being conducted at the Mayo Clinic at present.

CASES STUDIED

The clinical observations in 150 consecutive cases of stiff painful shoulder, in which manipulation under anesthesia, surgical excision of calcified plaques or bursas, injection or needling was performed at the Mayo Clinic during the years 1942 through 1946, form the basis for this study. Detailed reports of 9 cases are included in this paper to illustrate certain points of diagnosis and treatment. It should be

2. McLaughlin, H. L.: Muscular and Tendinous Defects at the Shoulder and Their Repair, in Lectures on Reconstruction Surgery, American Academy of Orthopaedic Surgeons, Ann Arbor, Mich., Edwards Brothers, Inc., 1944, pp. 343-358; The Treatment of Injuries to the Shoulder, in Lectures on Regional Orthopaedic Surgery and Fundamental Orthopaedic Problems, American Academy of Orthopaedic Surgeons, Ann Arbor, Mich., Edwards Brothers, Inc., 1947, p. 92.

pointed out that statistics vary, depending on the type of practice. The majority of patients with painful stiff shoulders seen by the general practitioner are acutely disabled from some undue strain or exposure, whereas the orthopedic surgeon in his consulting practice usually sees patients who have a chronic condition attended by more or less atrophy of disuse. The condition in our cases was essentially of the latter type.

GENERAL OBSERVATIONS

In this study, 52 of 150 patients (35 per cent) were male and 98 (65 per cent) were female. The duration of symptoms varied from seven days to twelve years; 65 per cent had trouble less than one year, and 54 per cent had trouble less than six months. There was a definite history of trauma in 36 of the cases (24 per cent), and in 6 cases (4 per cent) there was a history of antecedent systemic infection. In the remaining 108 cases (72 per cent), in which the onset apparently was gradual and the course was intermittent, the causative factor was

Fig. 2.—*A*, calcified mass in the region of the subdeltoid bursa. *B*, and *C*, one month later. *B*, shoulder in internal rotation. *C*, in external rotation; absorption of the calcified mass has occurred.

not ascertained. In this series of cases the urinalysis gave negative results; results of flocculation tests for syphilis were negative in all cases; the sedimentation rate was rarely elevated; the concentration of hemoglobin and the leukocyte counts were within normal limits in all cases. Roentgenographic examination revealed calcification in 59 cases (39 per cent), osteoporosis in 34 cases (23 per cent) and nothing abnormal in 57 (38 per cent). Since the evidence of calcification depends on the degree of deposit, calcification doubtless was present in more cases than mentioned, because a certain percentage of patients do not show evidence of calcification at the time of examination although it may have been present at a previous time. We have seen patients in whom calcification appeared and disappeared with or without treatment. In other words the calcification may disappear spontaneously, as demonstrated in case 1 (fig. 2).

DIAGNOSIS

Pain, stiffness and local tenderness were the characteristic symptoms, and they often followed some heavy undue exertion, such as gardening, painting and washing walls, as in case 3. The pain was usually intermittent, aggravated by movement and often worse at night. It was occasionally so severe that opiates were required for relief. At times it was referred down the arm and into the hand, so that neuralgia was the principal presenting complaint. Commonly the pain extended upward into the side of the neck. The stiffness was principally a limitation of abduction and rotation, to a variable degree. The frozen shoulder was held in the sling position and permitted no motion except some apparent forward flexion and backward extension as a result of movement of the shoulder girdle. Nineteen per cent of our patients gave a history of bilateral involvement or the subsequent development of a similar condition of the second shoulder. Women commonly complained of inability to comb their hair or button their clothes behind them, and men were unable to get their hands into their hip pockets. The tenderness was maximal over the point of the shoulder laterally. This site corresponds to the tendinous portion of the rotator cuff near its insertion into the tuberosities of the humerus. At times there was some thickening in the overlying bursa, and the calcareous plaque beneath it could be seen and palpated through the intact skin.

It goes without saying that in all cases of painful stiff shoulder a detailed history of the illness should be obtained. The next essential procedure is a complete physical examination. A roentgenographic examination of the shoulder should always be made to rule out arthritis, fracture or the presence of organic bone disease, such as infection or primary or metastatic tumor, and to give evidence of the degree of osteoporosis or tendinous calcification present. In many cases there is decided osteoporosis, especially of the greater tuberosity and anatomic neck of the humerus.

The differential diagnosis of pain in the shoulder and arm will not be considered in this paper, as our experience at the clinic was well covered from the orthopedic, cardiac, thoracic, vascular and neurologic standpoints in a symposium on pain of the shoulder and arm published recently by Young, Olsen, Smith, Barker and Eaton.[3]

Differential Diagnosis.—Tuberculosis of the Shoulder Joint: Tuberculosis of the shoulder joint may be confused with a frozen shoulder in the early stage of the disease because both pain and stiffness

3. Young, H. H.; Olsen, A. M.; Smith, H. L.; Barker, N. W., and Eaton, L. M.: Symposium on Pain in the Shoulder and Arm, S. Clin. North America **26**:799-840 (Aug.) 1946.

are present, but as the tuberculosis progresses the destructive changes indicate its true nature. The persistent temperature, gradual onset, progressive severity of symptoms, atrophy and frequent presence of a primary tuberculous focus should make the physician suspect tuberculous arthritis of the shoulder. It is difficult to produce ankylosis, and it seldom takes place in tuberculosis; surgical operation, with prolonged fixation, is necessary. In cases of frozen shoulder, stiffness may develop within a few days of onset of pain, in spite of treatment for relief of pain, but true bony ankylosis is rare. Adhesions can be broken by manipulation and a satisfactory functional result obtained, but in tuberculosis, once the destructive changes have occurred, action of the joint is permanently lost. The roentgenographic examination is of value to the diagnosis. With the exception of bony atrophy and regions of calcification described in frozen shoulder, the joint appears to be normal. In tuberculosis of the joint, however, roentgenograms reveal atrophy and later destructive arthritis with areas of absorption in the head of the humerus. Aspiration or excision of tissue for microscopic study may be needed to clarify the diagnosis as a final measure in perplexing cases.

Tuberculous Bursitis: Tuberculous bursitis produces a bulging soft mass which may contain palpable rice bodies. Such bursas usually are anterior to the shoulder. Careful dissection and complete excision will cure many of these tuberculous lesions, and the results, we believe, will be improved by the administration of streptomycin (case 9).

Acromioclavicular Separation: Acromioclavicular separation follows severe injury and may be differentiated from frozen shoulder by demonstrating looseness of the joint on palpation. In complete separation a diagnosis may be made by mere inspection and demonstration of false motion; the roentgenograms will reveal wide separation of the articular surfaces, and a definite sulcus or depression also can be seen. In the acute stage of acromioclavicular arthritis local tenderness and swelling are present; in the chronic stage destructive or hypertrophic changes usually are revealed in the roentgenograms.

Fractures of the Glenoid Cavity: In cases of fractures of the glenoid cavity there is a history of trauma, and the roentgenograms should reveal an area of separation.

Fractures of the Greater Tuberosity of the Humerus: Fractures of the greater tuberosity of the humerous, with or without dislocation, may be recognized on palpation and by roentgenographic study. One of us (H.W.M.) has seen stiff painful shoulders due to the fracture of the glenoid cavity, and even dislocations go unrecognized even after roentgenograms have been taken.

Ruptured Supraspinatus Tendons: Ruptured supraspinatus tendons do not cause fixed or frozen shoulders, nor is the pain on movement as severe as in the presence of frozen shoulder. The patients have ability to move the shoulder, but abduction causes pain and the patient may not be able to bring the arm up beyond a right angle.

Infections of the Shoulder Joint: Infections of the shoulder joint or osteomyelitis involving it should offer little difficulty in diagnosis, since they are accompanied with temperature locally and generally, increased leukocyte count and roentgenographic observations.

Tumors: Tumors do not cause symptoms of pain and stiffness unless they are of great size, and then clinical and roentgenographic evidence will reveal changes in the bone.

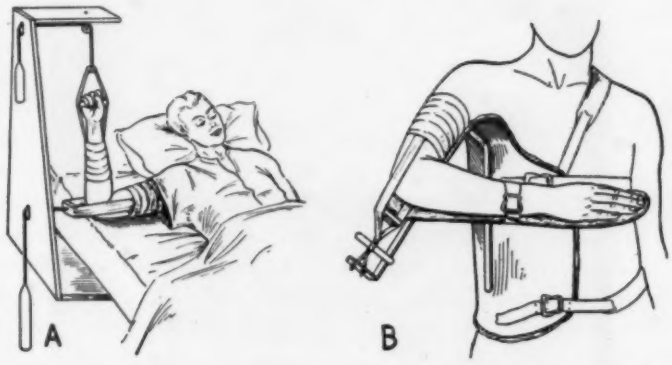

Fig. 3.—*A*, the recumbent method of treating the patient by means of traction in abduction and external rotation. *B*, adjustable abduction splint for ambulatory patient.

TREATMENT

The patient seen with the acute stage of the disease or with intense pain, local tenderness, slight fever and the arm maintained at the side for protection may be treated for a few days at home by rest in bed, local application of heat, increased intake of fluid, maintenance of elimination and traction, together with administration of adequate anodynes. Abduction should be encouraged, and conventional diathermy and roentgen therapy may be included, after which patients who have painful stiff shoulders often are relieved of their symptoms. When the patient is seen with the disease in the subacute recurring stage, after much of the pain has subsided and residual soreness and stiffness, aggravated by movement, persist, further examination should then be made to exclude calcification, traumatic lesion or tumor. Conventional diathermy, radiant heat, stretching and active and assistive exercises should be carried out routinely. If there is diffi-

culty in obtaining abduction, traction may be employed, or manipulation followed by abduction treatment in a splint or cast (fig. 3). In cases in which definite swelling of the bursa occurs as a result of effusion or hemorrhage, aspiration should be done. If murky turbid fluid and rice bodies are present, inoculation of animals with the fluid or excision of the bursa and microscopic studies should be performed to rule out tuberculosis (fig. 4).

Physical therapy (including baking, massage, conventional diathermy and active and assistive exercises) was used for the relief of all of the 150 patients, irrespective of the other forms of treatment. When conservative treatment failed to give relief of symptoms, surgical treatment was carried out.

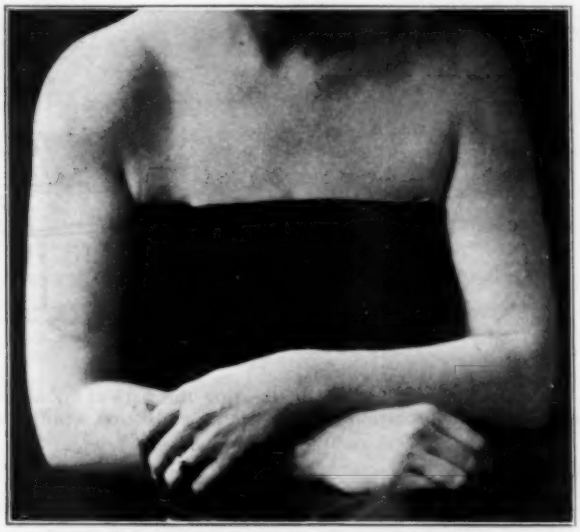

Fig. 4.—Tuberculosis of the right subdeltoid bursa bulging forward as a result of compression by the deltoid muscle.

At open operations on the service of one of us (H.W.M.) we usually employ an anteromedial split deltoid incision to expose the subdeltoid bursa. Rotation of the arm may be required to bring into view the calcified deposit, which appears as a raised whitish yellow patch surrounded by a circular band of inflamed tissue. On incision through the bursal wall, milky fluid, due to rupture of the calcified mass, may be encountered. The degree and the consistency of the calcification vary considerably; the calcareous deposits may be granular or of "toothpaste-like consistency." The tendinous cuff may have numerous connected or distinctly separate deposits of calcium, and these may extend into the bone. Curettage of this calcified deposit may not

remove it, as it may have permeated the degenerated fibrotic tissue to such an extent that excision may be necessary.

Since stiffness tends to persist or recur in spite of surgical excision of calcareous deposits, needling, to break up such deposits, or manipulation, to rupture adhesions, and abduction with external rotation exercises and physical therapy were employed routinely after operation. Patients practice abduction while standing with the shoulder toward the wall. With each exercise they strive to gain several inches in the height the hand can be raised.

At times an adjustable abduction splint or cast with traction (fig. 3) is used. When manipulation is indicated we prefer to use general anesthesia. Afterward the arm is placed in abduction and external rotation for the next forty-eight hours, by tying the patient's hand to the head of the bed. Manipulation can be extremely hazardous because of the danger of producing a fracture of the neck of the humerus, especially when osteoporosis is present. If osteoporosis is extensive, the stiffness may be combated by placing the arm in abduction under traction and carrying on physical therapy. The degree of abduction is increased as improvement takes place (fig. 3*B*). Local injections of procaine hydrochloride or blocking of the suprascapular nerve may give added benefit. Application of heat with active, passive and assistive exercises must be carried out daily, and the result obtained depends to a large extent on the cooperation of the patient. Manipulation is of prime importance and should be executed carefully and cautiously. Roentgenograms should be taken after operation or manipulation, to exclude possible fracture or dislocation.

In 69 (46 per cent) of the 150 cases of this series manipulation under anesthesia was performed; in 32 (21 per cent) additional cases manipulation with injections of procaine hydrochloride into the suprascapular nerve was used; in 31 (21 per cent) a needling operation was performed, to pierce and break up the calcareous deposits, and in 18 (12 per cent) surgical excision of the calcareous masses was performed.

Roentgen Therapy—Forty of the 150 patients (27 per cent) received roentgen rays in addition to other treatment, some of them prior to admission at the clinic.

The following comments by Leddy and Popp[4] apply to all patients with painful stiff shoulder treated by them and includes a much greater number of cases of acute lesions than of chronic. They stated that in the treatment of painful stiff shoulders repeated small doses of roentgen rays were employed frequently with relief of symptoms. Ordinarily the beam of roentgen rays was centered over the bursa at

4. Leddy, E. T., and Popp, W. C.: Personal communication to the authors.

the point of maximal tenderness, and if the condition was acute and the shoulder could not be moved comfortably, they gave three to four doses of 75 r each on alternate days. For the subacute stage or for chronic disease, they used 100 r once or twice a week, depending on how painful the shoulder was. They stated that the presence or absence of calcium in the bursa does not seem to make any difference as far as the result of roentgen therapy is concerned. Acute lesions have proved more amenable to this form of treatment than the more chronic lesions.

REPORT OF CASES

CASE 1 (*Rapid Absorption of Calcareous Deposit under Physical Therapy Alone*).—A housewife, 53 years of age, was seen at the clinic in 1946, at which time she stated that pain and puffiness of the left wrist had begun suddenly two weeks prior to admission and had disappeared in four days, but the left shoulder then had become painful, sore and stiff. She had had diathermy, with some benefit.

Examination of the roentgenograms showed evidence of calcified tendinitis (fig. 2*A*). The roentgenograms of the chest and teeth revealed nothing significant. Motion of the left shoulder was limited in all directions. There was a question of gout, as the patient had had pain in the big toes and gave a history suggestive of arthritis. When the concentration of uric acid was observed to be 3.4 units per hundred cubic centimeters of blood, the possibility of gout was ruled out. The sedimentation rate of the blood was 31 mm. per hour. Other laboratory tests revealed nothing of significance.

The patient was instructed in physical therapy and advised to continue with this at home. She was seen one month subsequently, at which time she was entirely relieved of the stiffness and soreness of the left shoulder and the roentgenograms showed no evidence of calcareous deposits (fig. 2*B* and *C*). The sedimentation rate was reduced to 17 mm. per hour. She had remained well as of the time of writing.

CASE 2 (*Painful Stiff Right Shoulder in Association with Coronary Sclerosis and Angina Pectoris*).—A man, 49 years of age, who had coronary sclerosis and angina pectoris, was seen in June 1944. At that time he complained of a painful stiff right shoulder. The roentgenograms revealed peritendinous calcification of the right shoulder. Manipulation, a course of five doses of roentgen rays and physical therapy were given. A subscapular nerve block also was carried out. The patient made a good recovery, and when he was seen three years later he had a normally functioning right shoulder.

CASE 3 (*Painful Stiff Shoulder Resulting from Unaccustomed Work by a Man of Sedentary Occupation*).—A man, 49 years of age, was seen in May 1943, because of stiffness, extreme pain and tenderness of the left shoulder. He had not been accustomed to any physical labor, and, because he was anxious to have a garden, he had used a hand plow for three days. Following this he had complete disability of the left shoulder. The roentgenograms revealed evidence of peritendinous calcification, and a diagnosis of "subacromial bursitis" was made. With rest and physical therapy the patient made a rapid recovery in ten days, and as of the time of writing, he had had no further trouble.

CASE 4 (*Frozen Right Shoulder Relieved by Manipulation and Physical Therapy*).—A housewife, 37 years of age, was referred to the clinic in June 1946. She

gave a history of pain in the right shoulder, of three months' duration; there had been progressive limitation of motion and she had been treated for osteomyelitis with penicillin and local application of heat.

Examination revealed a painful tender stiff right shoulder, and the roentgenograms revealed osteoporosis, with roughening of the greater tuberosity. The sedimentation rate on two occasions was 45 mm. and 58 mm., respectively, per hour. Manipulation was performed, at which time heavy adhesions were broken and the range of motion became normal. Nine months later the patient reported that she was well.

CASE 5 (*Frozen Shoulder, Resulting from Unusual Strain, Relieved by Manipulation and Physical Therapy*).—A woman, 49 years of age, who was seen in 1945, complained of pain in the left shoulder, of four months' duration. She stated that the pain, which was worse at night, had been felt first after she had cleaned house and that it was localized to the left side of the neck and shoulder but extended sometimes into the arm and hand. She had been treated with heat and massage at home, without benefit.

Examination disclosed decided limitation of motion and tenderness of the left shoulder, with nothing abnormal in the roentgenograms. Tests for uric acid, urinalysis, flocculation test for syphilis and the roentgenograms of the lungs revealed nothing abnormal. The concentration of hemoglobin and the leukocyte counts were normal.

The left shoulder was manipulated during sodium pentothal anesthesia, and the adhesions could be felt to give way. After this procedure, the shoulder joint could be put through almost normal motion. The patient then received physical therapy, including diathermy and massage, for about three weeks and was much improved. Two years later she wrote that she had had no pain the shoulder and that the motion was normal.

CASE 6 (*Unusual Strain Producing Frozen Shoulder, Unrelieved by Physical Therapy, but Relieved by Manipulation and Physical Therapy*).—A woman, 47 years of age, was seen in 1942, at which time her principal complaint was a painful left shoulder, of seven weeks' duration. Her disability had begun suddenly after she had pushed up a cellar door. The pain in the left shoulder gradually became worse and bothered her at night, and she was unrelieved by physical therapy consisting of baking, massage and diathermy.

Examination revealed stiffness and tenderness of the left shoulder. Roentgenograms did not reveal any bony lesion. Laboratory examination revealed nothing abnormal. The patient was instructed in physical therapy and advised to carry it out twice a day at home. She returned in three months with a typical frozen shoulder. Abduction was limited to 20 degrees, and there was decided limitation of rotation. The roentgenograms revealed only a mild degree of osteoporosis. With the patient under sodium pentothal anesthesia, the left shoulder was manipulated and the adhesions could be felt to break up. Practically full range of motion was obtained. She continued to have physical therapy. She was seen for other conditions over a period of four years following treatment, but the shoulder had remained well.

CASE 7 (*Postinfluenzal Painful Stiff Shoulder, with Calcification Relieved by Excision*).—A woman, 51 years of age, complained of a painful stiff right shoulder, of three years' duration. She stated that she had pain and swelling in multiple joints when she was 27 years of age and that her condition had been diagnosed as rheumatic fever. Since that time she had had sporadic trouble with her joints. The pain in the right shoulder had developed after influenza about three years

prior to admission and had become worse about ten months before examination. The pain was in the right shoulder and extended up the neck and down into the forearm and wrist; it had been severer at night. Three weeks before admission she had four treatments with roentgen rays and much physical therapy, without benefit.

Examination revealed limitation of motion with tenderness of the right shoulder and weakness of the grip in the hand. The roentgenologist reported calcification of the subdeltoid bursa of the right shoulder. Roentgenograms of the cervical vertebra showed some hypertrophic changes. The sedimentation rate was 27 mm. per hour.

A combination of regional and intravenous anesthesia was employed, and a calcified mass was excised from beneath the subdeltoid bursa in the insertion of the supraspinatus tendon. A chemical analysis of the material removed disclosed calcium carbonate and calcium phosphate. About ten months later the patient reported that she had no more trouble with her right shoulder.

CASE 8 (*Bilateral Painful Stiff Shoulders, with Calcification, Unrelieved by Conservative Measures, Treated by Manipulation and Excision Followed by Physical Therapy*).—The patient, a man 57 years of age, complained of aching and limitation of motion in the left shoulder, of three years' duration. He said that the onset of this trouble had followed an infection in his great toe. Two months prior to admission he had had similar symptoms in the right shoulder. Examination revealed stiffness and tenderness of both shoulders. The roentgenograms revealed peritendinous calcification of both shoulders. The sedimentation rate was 12 mm. per hour.

Roentgen rays were given to both shoulders on two occasions, without relief. Therefore, operation was performed on both shoulders and calcareous masses were removed from the cuff of rotator muscles by curettage. Eleven days later both shoulders were gently manipulated and observed to move freely. For a month prior to and for three and a half months after operation, the patient received physical therapy daily, and in four months he had almost normal motion, with only slight pain in either shoulder.

CASE 9 (*Clinical Tuberculosis of the Subdeltoid Bursa Treated by Incision and Removal of Rice Bodies, with Good Results*).—The patient, a woman 48 years of age, complained of pain in the right shoulder with swelling and stiffness. There was no history of trauma. She gave a history of urinary symptoms with passage of blood about twenty-three years prior to admission.

Examination revealed no loss of weight, and the temperature, blood pressure and pulse rate were normal. A soft mass was palpable anterior to the right shoulder. The urinalysis revealed albumin, erythrocytes and occasional pus cells. The roentgenograms of the shoulder, thorax, stomach, kidneys, ureter and bladder revealed nothing of significance. The roentgenograms of the spinal column showed evidence of spondylitis. Urologic examination, including inoculation of guinea pigs with material from both kidneys, gave negative results. The Wassermann reaction of the blood was negative. The blood cell count was normal. Aspiration of the swelling about the right shoulder yielded milky fluid, and a diagnosis of tuberculosis was made (fig. 4).

The bursal sac was incised, and rice bodies were removed. More than eight years later the patient reported that the shoulder, except for an occasional ache, had remained well.

SUMMARY AND CONCLUSIONS

Practically all of the patients of this series of 150 cases had had treatment of some type prior to coming to the clinic. Seventy-six per cent were between the ages of 40 and 60 years. Forty-six per cent had had symptoms of varying degrees of severity for more than six months. The principal complaint was disability resulting from pain and stiffness in the shoulder. Treatment was directed toward relief of pain and stiffness. Physical therapy had been given to all of the patients, and some received roentgen rays, needling or injection, without relief of symptoms. Therefore, in view of the continued disability, some form of manipulation or surgical treatment was deemed necessary at the Mayo Clinic. During manipulation the shoulder often gave way with an audible and palpable pop or crepitus. However, in some patients no such sudden release occurred, although some increase of motion was gained. In this group repeated manipulation or prolonged traction was necessary. Recumbency and abduction in external rotation, with traction by means of such apparatus as illustrated in fig. 3*A*, together with physical therapy, constituted a useful method of combating the more persistent conditions, especially in those patients who had extensive osteoporosis.

It is obvious from the foregoing comments that all patients with painful stiff shoulder were not relieved by any one method of treatment, in spite of the cooperation of the patient. Some methods of treatment may relieve pain but do not always relieve stiffness, and some form of manipulation and traction may become necessary. Furthermore, while conservative measures are indicated in the acute and subacute stages, in the more advanced and chronic stages manipulation or surgical treatment or both are indicated. By following such procedures we have obtained satisfactory functional results in 85 per cent of this series.

DISCUSSION

DR. RALPH G. CAROTHERS, Cincinnati: Dr. Meyerding mentioned trauma as one cause of the conditions listed. It is a well known fact that the Colles fracture occurs when one falls on the outstretched hand. Many persons do not realize that that same fall may not produce a Colles fracture but may produce fractures of both bones of the forearm or a supracondyle fracture of the elbow or a fracture of the clavicle. It is the same mechanism in any case. Therefore, it is evident that the same forces must be applied to the shoulder.

When a person falls on the outstretched hand and a Colles fracture results, the force is not all dissipated in the fracture of the radius, but the head of the humerus is momentarily jammed into the glenoid.

There is no mention made by the patients of pain in the shoulder, and, as usual, there is no recognition of any injury at that point. The cast or splint is applied to the wrist, and the wrist is carried in a sling. If the patient does not use that shoulder frequently from the start, by putting the arm up and behind and

going through all the motions, adhesions may develop. I have seen it happen in many cases. These adhesions are the source of the stiff painful shoulder and the type of shoulder which is cured by manipulation.

DR. ESLIE ASBURY, Cincinnati: Dr. Meyerding has brought before this society a timely and important subject, which deserves the consideration of everyone, especially of general surgeons. In spite of its prevalence, there seems to be a great deal of confusion among physicians concerning this condition.

Large numbers of persons suffer over long periods of time with frozen shoulder, often with extensive calcium deposits, and are treated with roentgen rays and physical therapy, without apparent benefit.

Unfortunately, in the last few years there has been too much propaganda against operation as a means of treatment.

I wish to speak particularly of the acute form of the condition, which is often seen in practice in a large city. The patient is usually a middle-aged man, unable to move his arm because of extreme pain. As Dr. Meyerding has pointed out, he may have sustained only a trivial injury. The roentgenogram, however, may show an extensive deposit, which obviously has been present for a long time without causing symptoms. Some factor, possibly the injury, initiates an active inflammatory reaction which causes the production of a great deal of fluid.

On examination, the subacromial region may be tender and bulging. Whether or not the roentgenogram shows a calcium deposit, surgical decompression is often worth trying because the procedure gives immediate relief. The operation is simple and can be performed on an ambulatory patient, in most cases under local anesthesia. Of course, when there are associated adhesions to be manipulated and broken up, general anesthesia is required. After manipulation or operation the patient must be carefully supervised and encouraged to carry out abduction and rotary shoulder exercises, in order to prevent the formation of periarticular adhesions.

DR. EDGAR L. GILCHREST, San Francisco: This is a subject that has interested me for twenty-five years. In fact, the first paper that I gave on this subject was presented before this association in French Lick, Ind., in 1924, so that I attended Dr. Meyerding's paper and his slides and motion pictures with much interest. He has given us a comprehensive review of this subject, but time did not permit him to go into many of the factors causing painful stiff shoulder.

Like the poor, the painful shoulder will always be with us, because the shoulder, when reviewed from an evolutionary standpoint, is an anatomic liability. It is a pendulous joint, doing a job it was never intended to do.

The various lesions that Dr. Meyerding showed were of the subacromial and of the subdeltoid bursas. I wish to confine my discussion largely to the bicipital syndrome, which accounts for much pain in the shoulder. By the bicipital syndrome I refer to the wear and tear, the complete destruction and rupture and the dislocation and elongation of the tendon of the long head of the biceps. In 1933 I reported an analysis of 100 cases before the Clinical Congress of the American College of Surgeons and showed that these lesions were not rare.

No one has contributed so much knowledge to the subject of attrition of the shoulder as the eminent anatomist, Dr. A. W. Meyer, former professor of anatomy at Stanford University, who called attention to various extracapsular lesions of shoulder in a series of articles in the ARCHIVES OF SURGERY in the early twenties. He concluded that occupation must play an important role, for when these shoulders are explored one observes that the changes are in no sense inflammatory. On the contrary, one sees a definite local area which has yielded to the stress and strain of toil and has been worn, shredded and frazzled. The tendon of the long

head of the biceps finally frays out like a rope, and the various strands take on a new and lower attachment.

My continued interest in this subject led me to present to this association in 1934 an analysis of 6 cases of dislocation and elongation of the long head of the biceps and to review and bring up to date the literature. Anyone interested in this subject can find this article in the *Annals of Surgery*, July 1936. This had been a neglected subject, and I could find no help in any textbook of surgery.

Meyer and his associates have seen over 50 cases of decided dislocation and many others of lesser degree in the dissection of one thousand arms. The condition in some of these was bilateral. In the complete review of the literature I saw no mention of an operation having been performed for the relief of this condition.

There are several factors which favor dislocation of this tendon, but time will not permit my discussing them.

The mechanism of production of the acute and recurrent types of luxation is brought about by external rotation and abduction of the arm over 90 degrees, in which position the tendon is reflected more, over and against the attachment of the articular capsule in the region of the lesser tuberosity.

Symptoms of a dislocated tendon are variable and depend on the onset and type. In most cases they are similar to those of a ruptured biceps tendon. The onset is usually acute. There is pain in the region of the bicipital groove, which may radiate down the muscle. This pain is increased on external rotation and overhead extension. There is also weakness of the arm. The pain and the weakness may be so great that the function of the limb is much impaired.

A diagnosis is not always made easily, especially if one does not bear this entity in mind during the examination of a shoulder. The symptoms may not be so pronounced at first, and many of the objective signs may be obscured by the tenosynovitis and the generalized soreness which result from the production of such a lesion. The history is valuable. In any disability of the shoulder, brought about by a sudden movement or by movements of external rotation and overhead extension, continued over a long period of time, the possibility of the production of a dislocation of the tendon of the long head of the biceps should always be considered.

My former associate, Dr. Piero Albi, and I have found the following test useful in verifying the diagnosis of dislocation of the tendon. If there is a recurrent dislocation of the tendon, one can at times reproduce the dislocation by having the patient bring his extended arms to overhead extension and external rotation holding, if possible, an equal weight in each hand, such as 5 pounds (about 13 cm.) dumbbells. The observer places himself either behind or in front of the patient and puts his fingers on the long head of the biceps. The patient is then instructed to lower his outstretched arms to the side in the coronal plane. When the arms reach an angle of from 110 to 90 degrees, a definite snap may be audible in the top of the injured shoulder and a sharp pain is elicited both in the shoulder and in the region of the bicipital groove. This snap is also felt by the fingers held over the belly of the biceps and the tendon of the long head. It gives the impression of a taut violin string that snaps as it slips into a grove of the bridge. Occasionally the vibrations produced by the snap may be visible in the long head of the biceps. This snap is not produced if the arm is lowered in internal rotation or if the belly of the biceps and the tendon of the long head. It gives the impression of a posteriorly, even though the arm is in external rotation. Since developing this test, I have observed the condition in my last 3 cases.

If the tendon is dislocated and the patient is seen early, an attempt should be made to reduce the dislocation by the following procedure, which I have used on

several occasions. The extremity, with the elbow bent and the forearm supinated in order to relax the tendon, is abducted passively and gently in the coronal plane to 90 degrees or more and simultaneously rotated internally. Sometimes it may be necessary to grasp the belly of the biceps as high as possible, near the deltoid muscle, pull it backward and hold it as the arm is lowered in the same plane, to help the replacement of the tendon and also to prevent a possible, although rare, immediate redislocation. Anesthesia may be required to overcome the reflex spasm of the structures in the shoulder.

If the patient is seen some time after the dislocation occurred, the treatment really will depend on the subjective symptoms and especially on the disturbances of function. If they are not severe, it may not be necessary to intervene surgically, as the tendon and the structures around the intertubercular sulcus will have adapted themselves to the new condition. If the patient is engaged in heavy work which requires constant use of his biceps, the best procedure is to operate early, as there is every reason to believe that, if he is having trouble a fairly long time after the accident, his condition will not improve, but will probably get worse.

The surgical repair varies according to the operative observations. If the structures around the groove are such that their repair will give assurance of a good result, this should be done and, if necessary, the groove should be deepened. An easier procedure, and one probably more satisfactory, is to repair the tear in the structures around the groove, after severing the tendon of the long head as high in the joint as possible, and then to suture this tendon to the coracoid process and to the tendon of the short head, as described previously. This has invariably given a satisfactory result.

DR. HENRY W. MEYERDING, Rochester, Minn.: I do not have anything to add, except to thank the men who have discussed the paper and have brought out some of the points that I did not have time to bring out.

ANATOMIC MECHANICS UNDERLYING GASTROJEJUNOSTOMY

With Particular Reference to Anterior or Antecolic Types of Anastomoses

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AND
JACOB A. GLASSMAN, M.D.
CHICAGO

THERE is a common belief that an anterior or antecolic anastomosis between stomach and jejunum has advantages over a posterior or retrocolic type of union. This belief is held for the simple gastroenterostomy of the Wölfler type as well as for the anastomoses that are done following resection of the stomach. It is not the purpose of this paper to offer a partisan view of the merits of either the antecolic or retrocolic procedure. It is assumed that both operations have their individual advantages, under varying conditions. There is a need for better appreciation of some of the mechanical and anatomic limitations which present themselves to the surgeon who does either operation.

The suggestion is made that when the omentum is thick and the mesentery of the transverse colon is fatty, one can bring a long loop of the jejunum around the colon easier and more safely than can be done by going through the mesocolon and attaching the jejunum to the posterior wall of the stomach. At the same time, it is also suggested that the long loop will avoid traction at the site of anastomosis. Even in the absence of a thick heavy mesentery and a ponderous omentum there are those who feel that an anterior gastroenterostomy has less technical pitfalls and can be more easily accomplished than a posterior gastrojejunostomy.

It is our purpose to point out certain facts relative to the measurements of the mesentery and call attention to the difficulty and danger which may attend the commonly employed anterior gastrojejunostomy. These dangers are more easily avoided if one is conscious of the variations in length of this mesentery and what relation the mesentery bears to the small intestine when they must both be passed circumferentially around the colon and its attached omentum.

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Read at the Fifty-Fifth Annual Meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 5, 1947.

After having had occasion to reoperate on several patients who had had previous anterior gastrojejunostomies elsewhere, we became interested in the mechanics involved in the dysfunctions and obstructions which we observed at the time of operation.

In order to evaluate our observations properly, we undertook a study of the relationship of the viscera, and we gave special consideration to the length of the mesentery (table). It was measured from the mesenteric edge of the bowel to its radicular attachments.

The mesentery is a broad fan-shaped fold, composed of two layers of peritoneum, which connects the small intestine to the posterior wall of the abdomen. The long free border of the fold contains the intestine within it. The other, or attached border, known as the radix mesenterii (root of the mesentery), is comparatively short, being only 6 or 7 inches (about 15 or 18 cm.) long; it is much

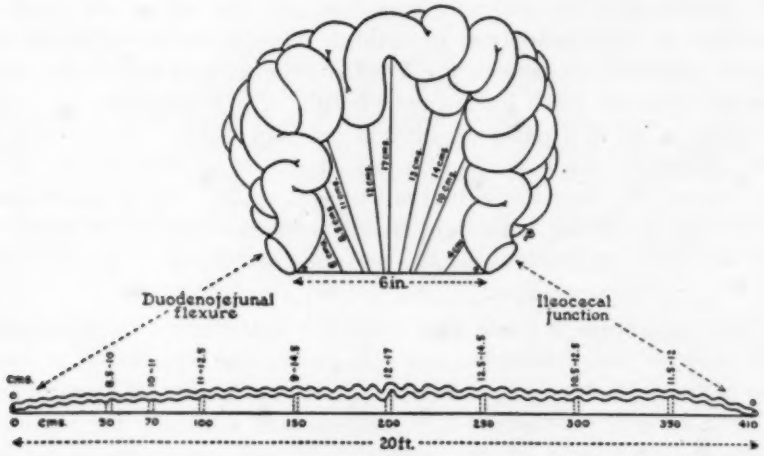

Fig. 1.—Diagrammatic illustration which shows compact folding of the mesentery. The mesenteric lengths which are given represent the average lengths in our series. The lower portion of the diagrammatic sketch shows the small intestine extended, and the location of the mesenteric lengths are indicated.

thicker than the part near the gut, for it contains between its layers a considerable amount of fatty extraperitoneal tissue, in addition to the large vascular trunks passing to the intestine. The root is attached to the posterior abdominal wall along an oblique line, extending approximately from the left side of the second lumbar vertebra to the right iliac fossa. In this course its line of attachment passes from the duodenojejunal flexure down over the front of the terminal part of the duodenum, then obliquely across the aorta, inferior vena cava, right ureter and psoas major muscle.

The unattached border of the mesentery is filled out to an enormous degree, so that, while the root measures only 6 or 7 inches, the free border is extended to about 20 feet (about 51 cm.), thus resembling a fan, one border of which may be twenty or thirty times as long as the other. The length of the mesentery, measured from its root to the attached edge of the intestine directly opposite, usually measures at its longest part about 6 inches (fig. 1). Between the two layers of the mesentery are contained: (*a*) the jejunal and ileal branches

of the superior mesenteric vessels, accompanied with the mesenteric nerve plexus and lymph vessels, (*b*) the mesenteric lymph glands, which vary from forty to a hundred and fifty in number, (*c*) a considerable amount of fatty connective tissue, continuous with the extraperitoneal areolar tissue, and (*d*) the intestine itself.

The mesentery begins above, immediately beyond the ending of the duodenum, that is, in the angle of the duodenojejunal flexure, and it ends below the angle between the ileum and ascending colon. It is short at each end, but soon attains the average length (fig. 1). While the root of the mesentery pursues at its attachment an almost straight line from one end to the other, if cut across a short distance from the posterior abdominal wall, it will here be seen to form a wavy or undulating line (fig. 2). Further away still, this condition becomes more

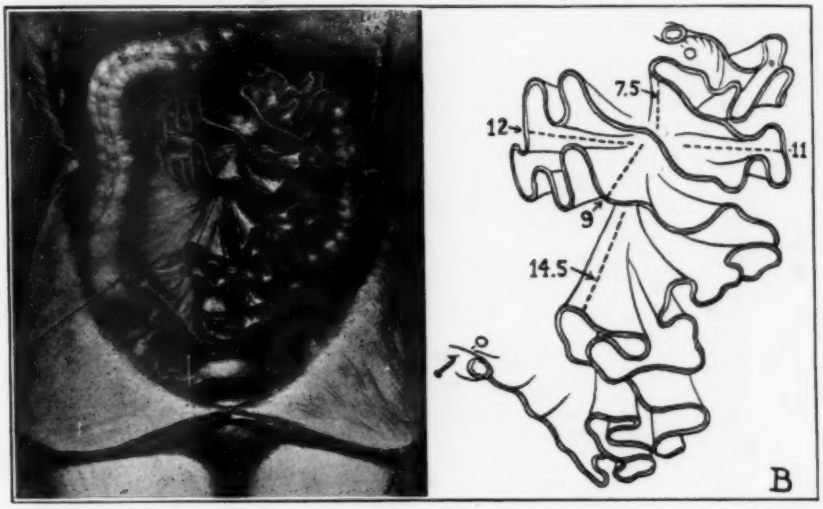

Fig. 2.—*A*, arrangement of mesentery with small intestine removed. The major and minor folds are clearly shown. (Kelly's Operative Gynecology.) *B*, a diagrammatic sketch of *A*, showing approximate measurements of the mesentery at various levels.

and more apparent; finally, if the bowel is removed by cutting through the mesentery close to its attachment to the intestinal wall, it will be seen that its free edge is not only undulating but frilled or plaited to an extreme degree (fig. 2). When shown in this way, it is seen that the plaiting, or folding, is not indiscriminate, but that the main folds, of which there are usually six, run alternately to the right and left. As a rule, the first fold runs to the left from the duodenojejunal flexure and goes to a coil of jejunum which lies under the transverse mesocolon and helps to support the stomach (fig. 2). The second fold passes to the right, the third to the left and so on up to the fifth and sixth which are usually small. From the margins of these primary folds, secondary folds project in all directions, and from these again even a third series may be formed.[1]

1. Cunningham, D. J.: Cunningham's Text Book of Anatomy, edited by A. Robinson, Baltimore, William Wood & Co., 1913.

MEASUREMENTS OF THE LENGTH OF THE MESENTERY FROM THE DUODENOJEJUNAL FLEXURE TO THE ILEOCECAL JUNCTION

The length of the mesentery was determined at 10 cm. intervals along the intestine. Actual measurement was from the radix to the mesenteric border of the intestine. Two extremes in measurements are recorded.

Measurements of the Length of the Mesentery from the Duodenojejunal Flexure to the Ileocecal Junction

Length of Small Intestine (Cm.)		Length of Mesentery (Cm.)
0	(duodenojejunal flexure)	0 — 0
10		6.5— 5.5
20		8.5— 8
30		8.5— 9
40		8.5—10
50		8.5—10
60		9 — 7.5
70		10 —11.5
80		10 —11
90		10.5—11.5
100		11 —12.5
110		10.5—13
120		10 —14
130		10 —13.5
140		10 —14.5
150		9 —14.5
160		10 —15
170		11 —15.5
180		11 —15.0
190		11.5—16
200		12 —17
210		12.5—16
220		12 —15.5
230		11.5—15.5
240		12 —15
250		12.5—14.5
260		12.5—14
270		12 —13
280		11.5—12.5
290		11 —12.5
300		10.5—12.5
310		10.5—12.5
320		11.5—12
330		12 —12.5
340		11 —12.5
350		12.5—12
360	(duodenojejunal flexure	12 —12
370		12.5—12
380		7 —11
390	(Ileocecal junction)	0 — 9
400		0 — 4
410	(Ileocecal junction)	— 0

In the application of these mechanical arrangements of the mesentery, which are fairly constant, one must not be misled by the plaiting and folding which the intestine itself shows (figs. 1 and 2). It is easy erroneously to conclude that one enjoys considerable latitude in the manner in which the intestine can be displaced laterally and superiorly in the abdominal cavity. It is true that the intestine is suspended from the root of the mesentery by the fanning out of this support (figs. 1, 2 and 3). The center of each mesenteric radius is along the oblique line of the root of the mesentery, and the circumference is the

circle which can be described by that radius from mesenteric root to the antimesenteric border of the intestine (figs. 4 and 5). This we propose to call the circle of maneuverability. The circumference represents

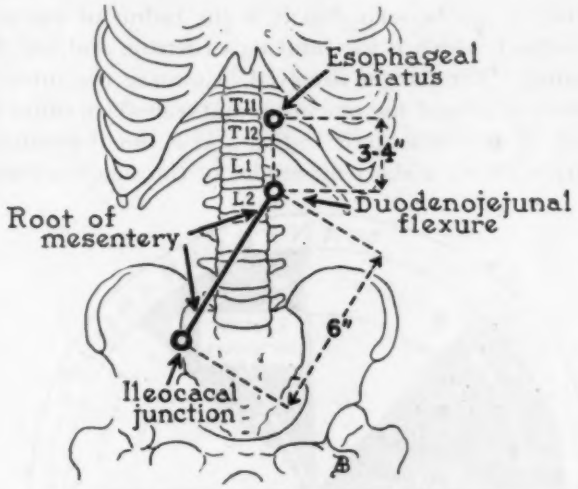

Fig. 3.—A diagrammatic illustration of the root of the mesentery and the relationship of the duodenojejunal flexure to the esophageal hiatus.

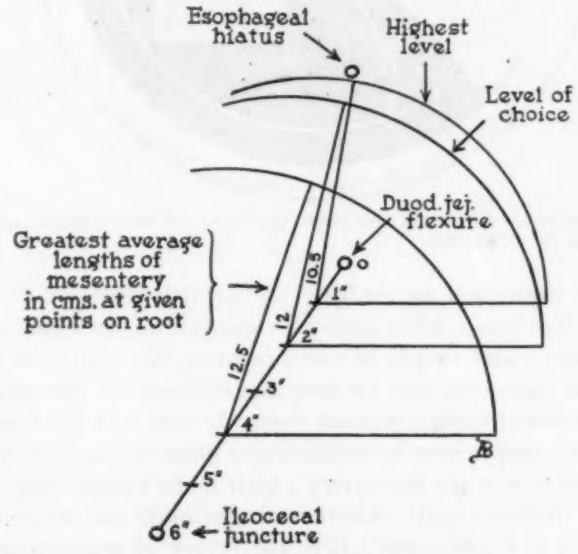

Fig. 4.—Diagrammatic illustration of the mesenteric root and the mesenteric lengths or radiuses of the circle of maneuverability.

the greatest distance which the mesentery will permit the intestine to be drawn away from its fixation at the mesenteric root. It is easy to

understand, then, that the farther one proceeds along the intestine, the more one tends to move the radius downward and to the right. This shifting circle of maneuverability limits and decreases the freedom in the elevation of the small intestine upward toward the diaphragm. Also, it can be seen that it is the radius of the circle (the mesenteric radius) which is the limiting structure, and not the folded plaited intestine. The danger involved in passing the intestine in an antecolic position around the omentum and transverse colon is limited by the length of the mesenteric radius and is not dependent on the folded intestine. With a short mesentery of the small intestine, there

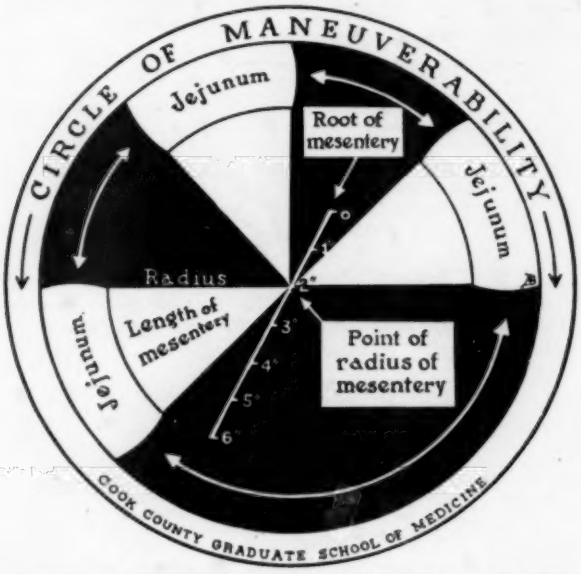

Fig. 5.—Diagram illustrating the mechanics involved in the maneuverability of the jejunum on its mesentery.

is a distinct limitation to the ease with which this can be brought around the transverse colon without constriction. In some instances, the arrangement and weight of the mesentery has interfered with the choice of the optimum site for anastomosis and has encouraged the use of an unusually long jejunal loop. It will add nothing to the freedom from compression by employing a point on the intestine more distally, because it is the mesentery which is the constricting element, and not the intestine itself. There is an optimum site where the mesenteric radius is longest and where the center of the root is highest (figs. 4 and 5). If the greatest ease is to be had in passing the intestine around the transverse colon and omentum and attaching it to the stomach, its site of attachment must be along the radius just described (fig. 6).

Two considerations commonly direct the choice of the level on the jejunum which is to be brought up and attached to the stomach in either of the gastrojejunostomies which we have mentioned in our previous discussion. The first consideration is given to the length of the mesentery of the small intestine which can be brought around the omentum and transverse colon, without causing constriction to either of them. If the jejunum can be passed around the transverse colon near the splenic flexure, there is less tendency to angulate the colon and likewise there is less omentum to be encircled by the mesentery of the jejunum. The second consideration which has influenced

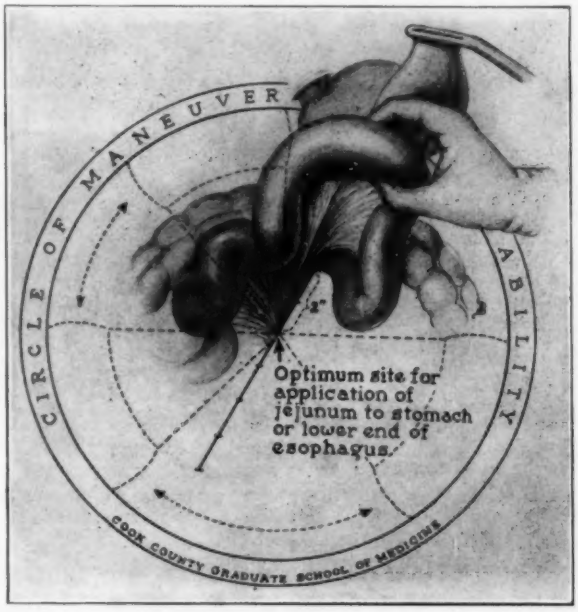
CIRCLE OF MANEUVERABILITY
2"
Optimum site for application of jejunum to stomach or lower end of esophagus
COOK COUNTY GRADUATE SCHOOL OF MEDICINE

Fig. 6.—This shows the actual application of the mechanical principle demonstrated in figure 5. At a point approximately 2 inches (about 5 cm.) caudally on the radix, the optimum length of jejunal mesentery is available.

surgeons in the choice of location for the jejunal stoma is the outgrowth of a series of experiments which has shown rather conclusively that there is an increasing tendency to develop stomal and jejunal ulcers as the site of the opening in the small intestine approaches the ileocecal junction. While these two considerations deserve attention, it is not an unusual practice for the surgeon to select a level on the jejunum which is so far removed from the optimum point of maneuverability that he produces an elevated angle in the transverse colon. This higher location lessens the likelihood of stomal or jejunal ulcer, but it also tends to increase the danger of partial obstruction of the

colon as well as disruption of the gastrojejunal anastomosis due to traction which develops by the short loop sustaining the encircled colon and omentum.

Many mistakes are made by surgeons because in their manipulations to bring the jejunum in apposition to the stomach they twist the jejunum on its mesentery and then fix it to the stomach (fig. 7). If the efferent loop of the anastomosis is made to pass behind the afferent loop along with the omentum and transverse colon, then in the presence of distention of either efferent or afferent loop there may be produced a mechanical ileus (fig. 7).

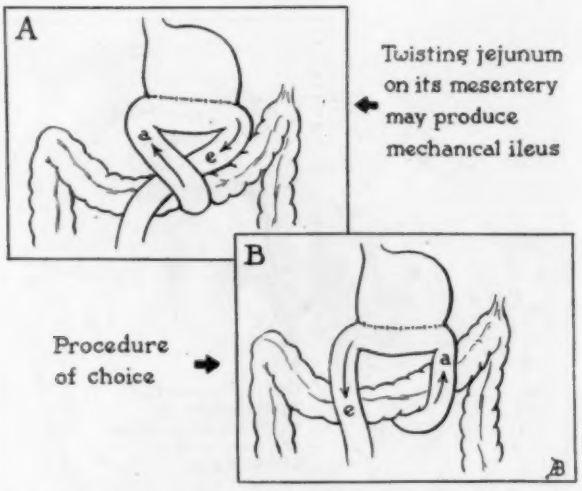

Fig. 7.—*A*, a mechanical error in anterior gastroenterostostomy that may produce obstruction. *B*, antecolic anastomosis with a workable mechanical hookup.

In complete gastrectomies the circle of maneuverability (figs. 3, 5 and 6) will be observed to permit the jejunum to be brought to the esophageal hiatus without undue tension. In actual measurement the duodenojejunal junction is usually located about the level of the first lumbar vertebra and slightly to the left. The esophageal hiatus usually occupies a position about the upper limits of the twelfth thoracic vertebra, slightly to the left. Thus, it will be seen that the distance through which the jejunum must pass is usually about 3 or 4 inches (about 8 or 10 cm.) (fig. 3). If the operator keeps in mind the circle of maneuverability and selects the loop of jejunum with the greatest radius and farthest to the left, he will fulfil his needs and offer the least possibility for undue traction, with little likelihood that the transverse colon or omentum will be distorted or compressed.

In total gastrectomies one is relieved of the worry of stomal and jejunal ulcers, because the acid-pepsin-bearing stomach has been re-

sected. The restrictions imposed by the fear of an ulcer having been removed, one can devote attention to the selection of an optimum site on the jejunum, which is chosen principally with regard to the circle of maneuverability. Our investigations have shown that in the majority of patients, this optimum site for application of the jejunum to the stomach or lower end of the esophagus in either gastrojejunostomies, with or without partial gastric resections, and in esophagojejunostomies when the entire stomach has been resected, is located about 20 to 28 inches (50 to 70 cm.) from the duodenojejunal junction (figs. 4, 5 and 6). The radius of the circle of maneuverability at this point will bring the center of the circle on the radix of the mesentery at a level nearest the lower border of the dependent part of the transverse colon.

There is a tendency on the part of surgeons who fear stomal or jejunal ulcers in anterior gastroenterostomies habitually to use a loop of intestine which is held by so short a mesentery that constriction of the colon can hardly be avoided.

SUMMARY

For surgeons who select or prefer the anterior or antecolic type of anastomosis, it is exceedingly important that they understand the limitations which are imposed on them by the variations in the length of the mesentery of the jejunum. It is also important that they become acquainted with the anatomy of the radix of the mesentery and familiarize themselves with its location, direction and extent. The relationship of the radix mesenterii to the attached small intestine must likewise be understood.

We have attempted, by a study of fresh specimens and cadavers as well as by measurements during actual surgical intervention, to determine the length of the mesentery of the small intestine at various levels. We have suggested the application of these measurements in establishing a principal of usefulness in anastomoses between the jejunum and the parts above the antrum of the pylorus. This mechanical principal we have termed the circle of maneuverability. The center of the circle is located at various points along the radix. The radius is represented by the mesentery, which suspends the intestine along any particular radius, and the arc or circle described is referred to as the circle of maneuverability.

720 North Michigan Boulevard.

MECKEL'S DIVERTICULUM

JERRY W. McROBERTS, M.D.
SHEBOYGAN, WIS.

MECKEL'S diverticulum is the commonest developmental anomaly of the intestinal tract. My experience with this condition is based on 8 cases in which the condition was diagnosed or verified at operation in my private practice and 2 cases observed while I was a graduate student. Before discussing the more interesting cases in some detail it would be fitting to review the surgical pathology of this anomaly.

The diverticulum is a persistent remnant of the vitelline duct or yolk stalk.[1] In early embyronic life it passed from the yolk sac along the umbilical cord to that portion of the midgut which later becomes the ileum. In normal circumstances the vitelline duct is obliterated at the end of the sixth or seventh week of embryonic life, but it may persist to a greater or lesser extent and be responsible for many symptoms and complications both in infantile and in adult life. The obliterative process begins at the umbilicus and extends toward the intestine. Consequently, the intestinal end of the duct persists more frequently. The commonest form is a finger-shaped sac, usually 3 or 4 inches (about 7.6 or 10 cm.) long and situated 3 or 4 feet (about 91 or 122 cm.) proximal to the iliocecal valve. As a general rule, it projects from the antimesenteric border of the intestine with its end lying free in the peritoneal cavity. However, there are a number of cases reported in which the diverticulum terminates in a thin fibrous cord which remains attached to the abdominal wall close to the umbilicus, or it may acquire a new attachment to the peritoneum within its length. The vitelline duct may remain patent and persist throughout its entire length, or, on the other hand, it may be so short that the ileum appears to open onto the surface of the abdominal wall.

In some cases only the umbilical portion of the duct remains as a persistent sinus discharging mucus. When it prolapses into the an-

Read at the Fifty-Fifth Annual Meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 5, 1947.

1. Beesly, L., and Johnston, T. B.: Manual of Surgical Anatomy, revised by J. Bruce and R. Walmsley, London, Oxford University Press, 1935, pp. 418-419.

terior aspect of the abdominal wall the condition is called an enteroteratoma, which is, of course, a misnomer.

There must be many persons who have a Meckel's diverticulum and have no symptoms related to it. The discovery of the diverticulum in autopsy in patients who had no gastrointestinal symptoms during life bears this out. Nevertheless, the complications of a persistent portion of the vitelline duct are legion.

In order to describe the complications of this anomaly, it may be well to divide them into (1) intrinsic complications which affect the diverticulum itself and (2) extrinsic complications, affecting other portions of the intestinal tract.[2] Under the first heading may be grouped those in which the communication between the ileum and the diverticulum is a small one or later becomes completely obliterated. In this condition a cyst may form filled with mucoid material. Later on it may become infected and simulate symptoms of appendicitis. Occasionally, acid-producing glands, like those of the stomach, are seen in the mucous membrane of the diverticulum. This may explain the development of a so-called peptic ulcer in the sac. The ulcer may perforate or be the cause of hemorrhage. Sometimes islands of pancreatic tissue are seen in the wall of the diverticulum. From these remains it is possible to explain the presence of an adenoma in the wall of the diverticulum.

The extrinsic complications arise, in the main, from the action of a persistent whiplike fibrous cord attached to the apex of the diverticulum. This may act as a fulcrum around which a volvulus is formed, or it may act as a snare in which a hernia develops. It is possible, too, for the diverticulum itself to prolapse into the lumen of the ileum and thereby cause intussusception. A free diverticulum filled with intestinal contents may, by its own weight, provide a fulcrum for a volvulus.

My interest in this condition was aroused in 1933, when I had the opportunity of seeing 2 patients in two successive days with two illustrative distinct complications. The first was in a young man whose chief complaint was the passage of bright red blood from the rectum on several occasions. Complete physical examination, including gastrointestinal roentgenograms, gave negative results. A proctoscopic examination revealed nothing abnormal. The operating surgeon surmised that bleeding might be from an ulcer in a Meckel's diverticulum. It was a dramatic exhibition when he was able to demonstrate a well formed Meckel's diverticulum which showed a large ulcerating lesion at its tip. Micrscopic examination of the tissue revealed the presence of acid-producing glands similar to those seen in the stomach.

2. Illingworth, C. F. W., and Dick, B. M.: Textbook of Surgical Pathology, London, J. A. Churchill, Ltd., 1935, pp. 476-478.

The second patient was a middle-aged man who complained of abdominal distention with cramplike pains in the middle aspect of the abdomen, frequently accompanied with vomiting. In this case the roentgenogram showed that he had a partial obstruction in the distal portion of the ileum. At operation a large Meckel's diverticulum was seen, which was adherent to adjacent loops of the small bowel and, because of this, was compressing and partially obstructing the terminal portion of the ileum. In both these patients, the diverticulum was excised at its base and the opening in the ileum was closed satisfactorily by the use of Connell's suture.

Since 1938 I have operated on 8 patients in whom this anomaly was present. I will not go into detail concerning all of them, but there are 3 cases that are worthy of description.

REPORT OF CASES

A boy, 16 years of age, was first seen in January 1940. He had had recurring bouts of abdominal pain, vomiting and obstipation ever since birth. At the time of his admission to the hospital he had been vomiting for four days and during this time had not had a bowel movement. His temperature was 98.6 F.; his pulse rate was 114, and respirations were 28. The white blood cell count was 7,000, with 77 per cent neutrophils and 22 per cent lymphocytes. Urinalysis showed no abnormalities. A roentgenogram of the abdomen was taken and revealed several loops of decidedly dilated small bowel, probably the jejunum. These dilated loops of small bowel showed a decided tendency for paralleling. The diagnosis was ileus.

The patient was prepared for operation, a suction tube was placed in the stomach, and he was given solutions intravenously. The following morning an exploratory laparotomy was performed through an incision of the right lower rectus. A long distended Meckel's diverticulum was seen, firmly bound by its tip to the peritoneum in the left lower aspect of the pelvis. It was pulling on a loop of ileum, obstructing its lumen. The proximal ileum was distended, and the wall was greatly thickened. The diverticulum was freed from its attachment to the pelvis and excised. The stump was inverted by purse string sutures in three layers. Postoperatively, intestinal drainage was continued by suction for a period of four days. His fluid balance was satisfactorily maintained by intravenous administration of dextrose and isotonic sodium chloride solutions. He was also given neostigmine methylsulfate, 1 ampule (1 cc.) three times a day. His postoperative condition was satisfactory. For the first three days his temperature varied between 102 and 103 F. Thereafter, his temperature was normal. An enema was given on the morning of the third day, with good results. He left the hospital sixteen days after admission and two weeks after his operation, in good condition. He had no recurrence of his previous symptoms and remained well. The pathologic report, in brief, was chronic catarrhal inflammation throughout the wall of the diverticulum.

Case 2.—A man, 36 years of age, was seen in September 1942. His chief complaint was a continuous aching pain in the right lower quadrant of the abdomen, of two months' duration. Coincident with the pain he felt bloated and was conscious of a gurgling sensation in the lower part of the abdomen. He had never vomited, but at times he felt nauseated. His bowel movements were regular. He

had never passed any blood from the rectum. He had had a complete physical examination, including laboratory and roentgenologic study, at the Wisconsin General Hospital three weeks before the present examination. The significant observations of this examination were as follows: His temperature rose to 99.2 F. practically every day. His sedimentation rate was 16 mm. at the end of sixty minutes. Roentgenograms of the genitourinary tract showed the typical shadow of a horseshoe kidney. Urinalysis revealed no abnormalities. Roentgenograms of the gastrointestinal tract following a barium meal did not reveal any abnormality.

Because of the persistence of localized pain in the right lower quadrant of the abdomen, it was decided to do an exploratory laparotomy. On opening the abdomen, I observed a long thin appendix, bound down at the middle by dense adhesions. The appendix was removed. The small bowel was examined and a well developed Meckel's diverticulum was discovered to be present, about 3 feet (about 91 cm.) proximal to the ileocecal valve. There was a fibrous tip on the rounded end of the diverticulum, but it was not attached to any other tissue. The wall of the diverticulum felt thickened in some areas. The diverticulum was excised at its base, and the opening in the ileum was closed by three layers of chromic surgical gut. The patient made an uneventful recovery from the operation and had remained well as of the date of writing. The pathologic report of the diverticulum was as follows: The specimen consisted of a pouchlike portion of intestine, to which was attached a cotyledon of adipose tissue. A stringlike portion of fibrous tissue was in turn attached to the cotyledon. The lumen of the diverticulum was filled with bile-stained fecal material. On microscopic examination the diagnosis was diverticulum, showing chronic inflammatory changes.

CASE 3.—A man, 36 years of age, was seen in the hospital on March 5, 1946. He stated that he had been aware of a definite dull aching pain in the right lower quadrant of the abdomen for several days. About twelve hours prior to admission the pain became severe and was associated with vomiting. On admission his temperature was 100.4 F.; the pulse rate was 84, and respirations were 22. Examination of the abdomen revealed it to be slightly distended. There was a moderate degree of muscle spasm and rigidity in the right lower quadrant of the abdomen. The point of maximum tenderness was definitely located at McBurney's point. The white blood cell count was 16,000, with 83 per cent neutrophils. The urinalysis revealed albumin (1 plus), but there were no other abnormalities. He was taken to the operating room shortly after admission. The diagnosis at this time was peritonitis, probably due to a ruptured appendix.

The abdomen was opened through McBurney's incision. On opening the peritoneum a considerable amount of turbid, foul-smelling fluid was found. While I was preparing to expose the cecum and appendix, a well formed Meckel's diverticulum came into view. There was a small perforation at its tip, from which liquid and gas were escaping. The diverticulum was excised at its base and the ileum closed by three inverted layers of chromic sutures. A drain was placed in the right lower quadrant of the abdomen, and the wound was closed.

Postoperatively he received intravenously several injections of 5 per cent dextrose and isotonic sodium chloride solutions. Gastric suction was maintained for a period of two days. The patient also received 1,000,000 units of penicillin G, twice daily for three days. His postoperative temperature was never higher than 100.6 F. The suction tube was removed on the second day. He left the hospital two weeks after his operation in good condition. He returned to work about a month after his operation and had remained free from gastrointestinal symptoms to this date.

The pathologic report was as follows: The specimen consisted of a pouchlike portion of tissue measuring 3 by 3 by 2.2 cm. The serosa was dull and par-

tially covered with a gray exudate. The serosal vessels showed a decided degree of injection.

Microscopically, all coats showed a moderate diffuse infiltration of white blood cells. The mucosa had been partially destroyed. There was no evidence of a malignant condition, and no glandular tissue was seen. The diagnosis was subacute diffuse diverticulitis.

Other Cases.—The remaining five diverticula were discovered in routine laparotomy operations and are not especially interesting. Three of them were excised at their bases. In two instances the diverticulum was thin walled and small enough to be inverted by purse string sutures into the lumen of the bowel. All the patients recovered without incident.

1001 North Eighth Street.

DISCUSSION

Dr. Fred F. Attix, Lewistown, Mont.: My interest in Meckel's diverticulum dates back about twenty-five years, at which time I was interested in observing a boy about 7 years of age who had had his appendix removed some three months previously. He lived in a rural section, and he had been told by his physician that he need have no fear of taking laxatives, as his appendix had been removed.

The boy did not show any improvement following his operation, and after a period of three months became seriously ill, so much so that the parents recognized that his condition was serious. They transported this boy about 90 miles over rough mountain roads to the hospital. He died within a short time after admission, and on autopsy I observed a strangulated gangrenous loop of ileum, about 3 feet (about 91 cm.) long, with extensive pelvic peritonitis which resulted in death.

With the possibility of the existence of Meckel's diverticulum in mind, I now explore the abdomen for this condition whenever some infection does not prevent such exploration and when it is not indicated that such a procedure might be dangerous to the patient.

I treated a man, aged 52, who was married and was a loader-laborer.

His health had been usually good. He had been kicked by a horse at the age of 5 years. No serious complications resulted. He wore a truss for a right inguinal hernia. His physician had attended him on Aug. 2, 1947, because of epigastric pain and vomiting during the previous night. Enemas gave some relief from nausea, vomiting and pain for three days, when pain and distress in both lower quadrants of the abdomen, accompanied with nausea and vomiting returned.

He was admitted to the hospital on August 5. A roentgenogram of the abdomen revealed a stepladder bowel. There was considerable generalized tenderness in the lower part of the abdomen. Wagensteen suction was started, and dextrose was administered intravenously. His temperature was 99 F.; the pulse rate was 68, full and regular, and the respiration was 20. Systolic blood pressure was 126 and diastolic 80. His red blood cell count was 5,050,000; white blood cells were 17,350, with hemoglobin 16.4 Gm., stab forms 5, segmented forms 85 and lymphocytes 7. The blood group was RH, 2 plus, and nonprotein nitrogen was 375 mg. A suitable donor was found and a blood transfusion (500 cc.) given.

Through a low midline incision, the lower part of the abdomen was explored and a large acute mass was encountered. There was a long (12 cm.) edema-

tous Meckel's diverticulum, with the distal end adherent to the posterior wall and the dome of the bladder, behind which a 12-inch (about 30 cm.) loop of ileum proximal to the base of the diverticulum had been telescoped beneath and had become strangulated and gangrenous. A localized abscess had developed at the intestinal wall in this segment. The surrounding structures were walled off with gauze packs, and clamps were applied obliquely to the proximal and distal portions of the ileum and severed by cautery. The intervening mass was dissected free and removed. The freed ends were approximated and delivered in the incision for secondary closure, which was done two months later when the physical condition was satisfactory, following treatment with repeated blood transfusions, amino acids, a dextrose solution in isotonic sodium chloride solution containing vitamin B factors, and other supportive measures necessary to combat the physical condition resulting from excessive drainage from the ileostomy opening.

DR. C. D. BENSON, Detroit: Dr. McRoberts' cases have all been of lesions in adults. I would like to give my experience with some of these lesions in infants and children at the Children's Hospital in Detroit.

Out of the group that my associates and I have studied who have had complications, there were 16 patients with such lesions. The cause of admission to the hospital was hemorrhage in 6. In 4 there was massive hemorrhage, and the specimen showed aberrant gastric tissue in the Meckel's diverticulum in all except 1 who had aberrant pancreatic tissue. Four were admitted to the hospital because of repeated abdominal pain and 2 because of umbilical discharge. Of this group, in 6 the Meckel's diverticulum was attached to the umbilicus. Nine had resection of the Meckel's diverticulum, and the ileum was closed at a 45 degree angle. Three required resection of the ileum, including the Meckel's diverticulum, and an end to end anastomosis. Thirteen of these patients made good postoperative recoveries.

There were 3 deaths in the group. The deaths occurred in the older group of children, 8, 9 and 11 years, respectively. They all had had symptoms of abdominal pain of over forty hours' duration. One had a perforated diverticulum with peritonitis, and the other 2 had intestinal obstruction with gangrene of the bowel, requiring resection.

In addition there was 1 patient, a young man 18 years of age, who came into the hospital with massive intestinal hemorrhage. He was studied roentgenologically by barium enema and hourly roentgenograms of the small bowel, but no Meckel's diverticulum could be demonstrated. I think that that has been experienced repeatedly by others and bears out the point of the futility of attempting to demonstrate Meckel's diverticulum by roentgenologic studies. At operation this patient had a wide stoma at the base of Meckel's diverticulum, but resection was carried out, and he made an uneventful recovery. There was aberrant gastric tissue present in Meckel's diverticulum on microscopic examination.

About three months ago we saw a rather unusual location of Meckel's diverticulum in a newborn infant who was 10 hours old at the time of operation. The infant had a large omphalocele; the liver and the small bowel were in the sac. On resecting the sac and the skin, it was seen that the Meckel's diverticulum accompanied the omphalocele, attached to the amniotic sac, and its point of origin was not from the ileum but high in the jejunum. The Meckel's diverticulum was then resected and the jejunum closed, and the first stage closure of the omphalocele was done. In other words, this omphalocele was so large that one could not close it by layers, and we did the first stage closure as recommended by Ladd; the second stage will be performed later.

DR. J. W. MCROBERTS, Sheboygan, Wis.: I have nothing additional to add, except to thank Dr. Attix and Dr. Benson for their contribution.

I have five slides which illustrate this anomaly, particularly the cases I discussed.

A 16 year old boy had a well formed Meckel's diverticulum, with a fibrous whiplike cord attached to the left aspect of the pelvis (slide shown). This, pulling out the ileum, caused intermittent obstruction. The proximal loop of the ileum was greatly distended.

A 36 year old man had indefinite symptoms of pain and gurgling sensations in the lower part of the abdomen (slide shown). The diverticulum on the antimesenteric side of the bowel is rather well illustrated. He made a quick recovery and had no recurrence of the symptoms following excision of the lesion.

Another slide illustrates the common type that Dr. Benson described; the fibrous tip of the diverticulum remains attached to the abdominal wall in the region of the umbilicus (slide shown). Another slide is of the Meckel's diverticulum, which shows perforation and is supposed to represent the gas and liquid escaping from the perforation (slide shown). The last slide shows the condition in which there is aberrant gastric tissue in the mucous membrane and bleeding (slide shown).

ARTERIOVENOUS FISTULA OF THE LUNG

Treated by Ligation of the Pulmonary Artery

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ARTERIOVENOUS fistula in the peripheral circulatory system, though uncommon, has been a subject of surgical discussion through the years. In contrast, similar lesions in the pulmonary circulatory system have received attention in the literature only recently. The rarity of this pathologic condition is suggested, or its lack of recognition is emphasized, when it is noted that no mention of it is made in Brenner's complete treatise[1] in 1935 on the pathologic conditions of vessels in the pulmonary circulation and that only 12 cases were recorded in the literature to November 1947.

REVIEW OF THE LITERATURE

The first authentic case of cavernous hemangioma of the lung with typical signs, including cyanosis and polycythemia, was reported by Rodes[2] in 1938. The cause of death was pulmonary hemorrhage, and at autopsy there were seen three hemangiomas with communicating openings between arteries and veins. Other similar cases in which operation was not performed have been reported by Smith and Horton,[3] Goldman,[4] Sisson, Murphy and Newman,[5] Rundles,[6] and Makler and Zion.[7]

From the Departments of Surgery and Medicine, University of Colorado Medical Center.

Read at the Fifty-Fifth Annual Meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 6, 1947.

1. Brenner, O.: Pathology of Vessels of Pulmonary Circulation, Arch. Int. Med. **56**:211 (Aug.); 457 (Sept.); 724 (Oct.); 976 (Nov.); 1189 (Dec.) 1935.

2. Rodes, C. B.: Cavernous Hemangioma of the Lung with Secondary Polycythemia, J.A.M.A. **110**:1914 (June 4) 1938.

3. Smith, H. L., and Horton, B. T.: Arteriovenous Fistula of the Lung Associated with Polycythemia Vera, Am. Heart J. **18**:589, 1939.

4. Goldman, A.: Cavernous Hemangioma of the Lung: Secondary Polycythemia, Dis. of Chest **9**:479, 1943.

The first successful surgical removal of one of these hemangiomas was recorded by Hepburn and Dauphinee[8] of Toronto, in 1942, who noted a prompt relief of symptoms following pneumonectomy. Similar results with the same procedure were reported in 1944 by Adams, Thornton and Eichelberger[9] and by Jones and Thompson.[10] An article by Janes[11] in 1944 described the local removal of three pulmonary hemangiomas in two stages, with successful results. A report by Beierwaltes and Byron[12] and one by Burchell and Clagett[13] described cures by lobectomy.

Other cases have been reported, but have not yet been published. Lawrence[14] at the Rocky Mountain Radiological Society meeting in 1947 reported 2 patients successfully treated surgically. Bisgard[15] at the Central Society for Clinical Research reported a patient treated by lobectomy. At the same meeting, Goldman[16] stated that his previously reported patient was now relieved after pneumonectomy and that he had observed the same condition in an older brother of the patient. At the 1947 meeting of the American Society for Thoracic

5. Sisson, J. H.; Murphy, G. E., and Newman, E. V.: Multiple Congenital Arteriovenous Aneurysms in the Pulmonary Circulation, Bull. Johns Hopkins Hosp. **76**:93, 1945.

6. Rundles, R. W.: Hemorrhagic Telangiectasia with Pulmonary Artery Aneurysm: Case Report, Am. J. M. Sc. **210**:76, 1945.

7. Makler, P. D., and Zion, D.: Multiple Pulmonary Hemangiomata, Am. J. M. Sc. **211**:261, 1946.

8. Hepburn, J., and Dauphinee, J. A.: Successful Removal of Hemangioma of the Lung Followed by the Disappearance of Polycythemia, Am. J. M. Sc. **204**:681, 1942.

9. Adams, W. E.: Thornton, T. F., Jr., and Eichelberger, L.: Cavernous Hemangioma of the Lung (Arteriovenous Fistula): Report of a Case with Successful Treatment by Pneumonectomy, Arch. Surg. **49**:51 (July) 1944.

10. Jones, J. C., and Thompson, W. P.: Arteriovenous Fistula of the Lung: A Report of a Patient Cured by Pneumonectomy, J. Thorracic Surg. **13**:357, 1944.

11. Janes, R. M.: Multiple Cavernous Hemangiomas of the Lungs Successfully Treated by Local Resection of the Tumours, Brit. J. Surg. **31**:270, 1943.

12. Beierwaltes, W. H., and Byron, F. X.: Pulmonary Arteriovenous Fistula with Secondary Polycythemia: Report of First Case Treated by Lobectomy, J.A.M.A. **134**:1069 (July 26) 1947.

13. Burchell, H. D., and Clagett, O. T.: The Clinical Syndrome Associated with Pulmonary Arteriovenous Fistulas, Including Case Report of a Surgical Cure, Am. Heart J. **34**:151, 1947.

14. Lawrence, E. A.: Arteriovenous Fistula of the Lung: Treatment by Surgical Resection, read before the Midsummer Radiological Conference of the Rocky Mountain Radiological Society, Denver, Aug. 9, 1947.

15. Bisgard, J. D.: Pulmonary Arteriovenous Aneurysm: Surgical Management, Proc. Central Soc. Clin. Research **19**:46, 1946.

16. Goldman, A.: Pulmonary Arteriovenous Fistula with Secondary Polycythemia Occurring in Two Brothers: Cure by Pneumonectomy, Proc. Central Soc. Clin. Research **19**:19, 1946; Am. Rev. Tuberc., to be published.

Surgery, in discussion of Maier's[17] experience, other new cases were mentioned. In all cases recorded, obliteration of the fistula by excision of the lesion resulted in clinical cure.

It is obvious that the lesion is not as rare as at first supposed, and its recognition is becoming more general, as the cardinal signs have been so thoroughly described. Although only 12 cases, with 6 patients treated surgically, appears in the literature from 1938 to November 1947, the condition has been recognized and treated in many more cases lately. Just during the past year, many such cases have been reported to societies or mentioned in discussion, so that it is expected that a much larger number will soon be on record.

PATHOLOGIC PROCESS

The lesion is usually congenital and probably always multiple. While the cause of symptoms is an arteriovenous fistula, the actual formation may be called a cavernous hemangioma, or, as preferred by Burchell and Clagett,[13] a congenital arteriovenous varix, to denote its origin, structure and lack of malignancy. While this description is anatomically correct, it must be realized that physiologically the lesion is a peripheral venous-arterial fistula, or a peripheral shunt of venous blood which avoids or by-passes its normal area of oxygenation to return to the systemic circulation.

The possible relationship of pulmonary hemangioma to hereditary hemorrhagic telangiectasia should be noted. The latter disease is definitely inherited; there may be bleeding from the nose, mouth, lung or intestinal tract, due to telangiectasia. A case in which there was such disease was reported by Schuster[18] and another by Rundles,[6] the roentgenogram in the latter case being typical of arteriovenous hemangioma. In the cases of pulmonary hemangioma reported, it was common to see small hemangiomas elsewhere and there were suggestions of hereditary tendency, this being most striking in Goldman's[16] cases. The thoracic surgeon should bear in mind that the lesion is fundamentally a congenital telangiectasia, which may well be present below the diaphragm as well as in the skin or the chest.

SYMPTOMS AND SIGNS

The symptoms and signs present a typical syndrome due to the fistulous connections. Always present are cyanosis, clubbing of the fingers and toes and polycythemia, usually without abnormality of

17. Maier, H. C.: Arteriovenous Fistula of the Lung, read before the Annual Meeting of the American Association for Thoracic Surgery, May 28, 1947.

18. Schuster, N. H.: Familial Haemorrhagic Telangiectasia Associated with Multiple Aneurysms of Splenic Artery, J. Path. & Bact. **44**:29, 1937.

the heart. A bruit has been heard in many cases, but is not prominent, nor does it have the continuous buzz of fistulas in the systemic circulation; it is sometimes louder on inspiration. Dyspnea, dizziness, fatigue, faintness and thickness of speech are common secondary symptoms. More than half the patients had small capillary hemangiomas elsewhere, the skin, lips and palms being the most frequent sites. Splenomegaly was noted in only 2 cases.

The cyanosis is frequently delayed in appearance; while in some cases the condition was present at birth, in others it was not noticed for two to sixteen years. Until the congenital fistula becomes large enough to shunt a sufficient amount of venous blood into the systemic circulation, the skin may not look abnormal in color. Cardiac enlargement is unusual and, when present, may be attributed to small increase of cardiac work caused by fistulas in the pulmonary circulatory system.

A comparison between the well known syndrome of arteriovenous fistula in the systemic circulation and that of the pulmonary arteriovenous fistula has been well expressed by Burchell and Clagett.[13] Among the like effects are the bruit, the increase of cardiac output and blood volume and the dilatation of the vessels proximal to the fistula. Among the reversed or unlike effects are the high content of reduced hemoglobin in the arterial blood in cases of pulmonary fistula, as compared to the high content of oxyhemoglobin in the venous blood in systemic fistula, and a collapsing pulse in the hilar vessels instead of a collapsing pulse in the systemic arteries. Possible new effects also are mentioned as the effect of arterial hypoxemia, polycythemia and its consequent symptoms, hemoptysis and the potentiality of arterial emboli from venous thrombosis.

No difficulty should arise in distinguishing the polycythemia of arteriovenous fistula from polycythemia vera, though it is interesting to note that the diagnosis of polycythemia vera was erroneously made in 2 of the first 8 patients reported with this condition. In polycythemia vera, the signs and symptoms are: polycythemia, cyanosis, increased blood volume, enlarged spleen, normal size of the heart, and only occasionally a pulmonary lesion. In comparison, the patient with pulmonary hemangioma shows polycythemia, cyanosis, increased blood volume, club fingers, rarely a palpable spleen, practically a normal heart, not infrequently a murmur over the hemangioma and a characteristic roentgenographic shadow. There are further differential points: in polycythemia vera the white blood cell count is elevated, but not in hemangioma. The white blood cells in polycythemia vera show immaturity, but not so in hemangioma, and the arterial oxygen saturation is not low in polycythemia vera, but averages close to 70 per cent in pulmonary hemangioma.

Observations of the blood in pulmonary arteriovenous fistula are characteristic. In the reported cases, the erythrocyte count varied from 7,000,000 to 11,500,000, while the white cell and platelet count remained normal and without changes in the blood smear. The hemoglobin ranged from 118 to 140 per cent. The bood volume was increased, averaging about 170 per cent of normal. This was caused chiefly by a high cell volume, giving a hematocrit reading of about 75 per cent. In all there was necessarily a low oxygen saturation of arterial blood, the average reported being from 70 per cent to 77 per cent of normal, while there was an increased arterial blood oxygen capacity.

ROENTGENOGRAPHIC OBSERVATIONS

Roentgenographic observations are practically diagnostic. There are one or more irregularly rounded fairly discrete shadows, seen anywhere in the lung field, of varied size, but usually not over 4 cm. in diameter, having a vascular tail extending toward the root of the lung. The whole makes a comet-shaped shadow, which, furthermore, with fluoroscopy may usually be seen to pulsate.

It is probable that these shadows are permanent and present from birth. Among the reported cases, it was possible to unearth old roentgenograms in 2, the patients aged 2 and 7 years, respectively, at the time of earlier roentgenograms. In both, identical shadows existed.

Interestingly enough, a pulmonary lesion in polycythemia vera has been described (Hirsch[19]). The picture is one of circular shadows of varying density in any portion of the pulmonic field. This lesion is sharply circumscribed and definitely outlined and does not give the comet appearance of a mass with a vascular tail. Furthermore, the shadow is not permanent, does not pulsate and may disappear in three weeks.

Injection of 70 per cent iodopyracet ("diodrast") into the basilic vein shows prompt filling of an arteriovenous aneurysm and establishes the diagnosis of blood vessel tumor, as well demonstrated by Lawrence[14] and others. It must be remembered that the injection of this radiopaque substance into the blood is not entirely without danger, and fatalities have been reported. Attempted angiography for this lesion in 1 case[5] resulted in death, believed to be caused by sensitization.

REPORT OF A CASE

The patient, first seen Oct. 19, 1944, was a Mongolian, born in China, aged 31 and a cook by trade. His complaint was fatigue and weakness of the legs for two and one-half years. While language difficulties prevented our obtaining a full

19. Hirsch, I. S.: Pulmonary Changes in Polycythemia Vera, Radiology **26**:469, 1936.

history, it was ascertained that he had been rejected by the army in 1941. He then began to feel tired and have dizzy spells and noticed weakness, particularly in his legs. About this time he noticed that he became short of breath on climbing stairs or lifting heavy objects. He would be so tired at night that he could not sleep. He quit his work at a restaurant because he did not feel well, but had worked intermittently since. He stated that he thought that his weakness and fatigue were increasing. He had lost 10 pounds (4.5 Kg.) in weight since 1942.

His past history was not relevant. He had worked in cafes most of his life. He stated that he thought he had been fairly well for two and a half years prior to examination. He had noticed clubbing of the fingers for many years and said that he thought that his skin had always been somewhat blue.

The patient was a fairly well nourished Chinaman, who looked cyanosed but not acutely ill. His height was 65 inches (about 165 cm.) and his weight 112 pounds (51 Kg.). His temperature and pulse rate were normal. Cyanosis was apparent in the skin, nail beds and mucous membranes, in spite of his naturally dark skin. A small hemangioma was noted on the lip. The chest was normal to percussion and auscultation with the exception that a soft to and fro murmur was

Fig. 1.—Clubbing of the fingers of the patient on first entry.

heard high in the right axilla, this murmur, or bruit, was best heard when the patient was lying down and straining his abdominal muscles. The heart showed no enlargement or other abnormality. The blood pressure was 96 systolic and 60 diastolic. The abdomen was normal and the spleen not palpable. The fingers and toes were decidedly clubbed.

Laboratory observations were as follows: Red blood cells numbered 7,050,000 and white blood cells 7,500, of which 77 per cent were polymorphonuclear cells, 19 per cent lymphocytes and 4 per cent endothelial cells. The hemoglobin was 19.5 Gm., or 130 per cent. Cell indexes showed the cell volume to be 75 per cent, mean corpuscular hemoglobin 27.6 Gm., mean corpuscular volume 106.38, mean corpuscular hemoglobin concentration 26, color index 0.903, volume index 0.19 and saturation index 0.76. Whole blood volume was 4,575 cc., of which the plasma volume was only 1,144 cc., giving a hematocrit reading of 75 per cent. Per kilogram, the whole blood volume was 93.4 cc. and the plasma volume 23.3 cc. Circulation time, arm to tongue, varied from 8 to 11 seconds and from arm to lung from 4.5 to 6 seconds. The venous pressure was 12.0 cm. of water. Fasting blood sugar was 101 mg. per hundred cubic centimeters. Nonprotein nitrogen was 30

mg. and cholesterol 139 mg. per hundred cubic centimeters. Total plasma protein was 8.1 Gm. per hundred cubic centimeters, albumin 5.3 and combined globulin and fibrinogen 2.8. Plasma chloride as sodium chloride was 597 mg. per hundred cubic centimeters. Plasma chloride as chloride was 102.1 milliequivalents per liter. The tests for oxygen saturation in the blood were unsatisfactory under the wartime conditions existing at the time of examination, and the results were discarded.

The electrocardiogram (fig. 2) of October 20 (three limb leads, chest and left arm leads CL_2, CL_4 and CL_6) was interpreted as follows: The limb leads showed low voltage in the QRS segment. Lead I was the "W type" in the QRS segment. The PR interval was close to the upper limits of normal. There was a high voltage P wave in leads II and III. The T waves showed high voltage; the chest and left arm leads CL_2 and CL_4 and the ST segment in these two leads showed high take-off. There was no diagnostic pattern.

Roentgenograms of the chest revealed two areas of opacity in the right lung, one apparently in the upper and one in the lower part (figs. 3 and 4). Each

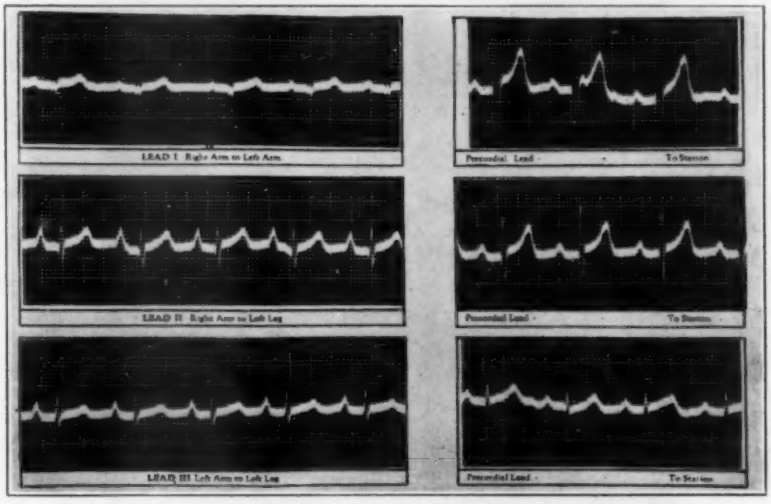

Fig. 2.—Electrocardiogram of Oct. 20, 1944.

area showed the typical comet-shaped shadow, with a central mass nearly 3 cm. in diameter and a tail extending toward the hilus. On fluoroscopy, the main opacities and the vascular tails were seen to pulsate. The size of the heart was within normal limits.

It was realized that pneumonectomy would eradicate these lesions. There was a serious objection to this on the part of the patient. After careful consideration of the problem and at the suggestion of Dr. Rudolph Nissen of Brooklyn, who was visiting the hospital at the time, it was decided that a preliminary test of ligation of the pulmonary artery be tried. It was felt that if this procedure accomplished nothing, pneumonectomy would still be in order.

On December 8, exploratory thoracotomy through an anterior incision was done by one of us. This approach did not give us as wide a view of the lungs as a long posterior one would have permitted. There were a few adhesions between the right lung and the parietal pleura, but on the whole the lung was free. A

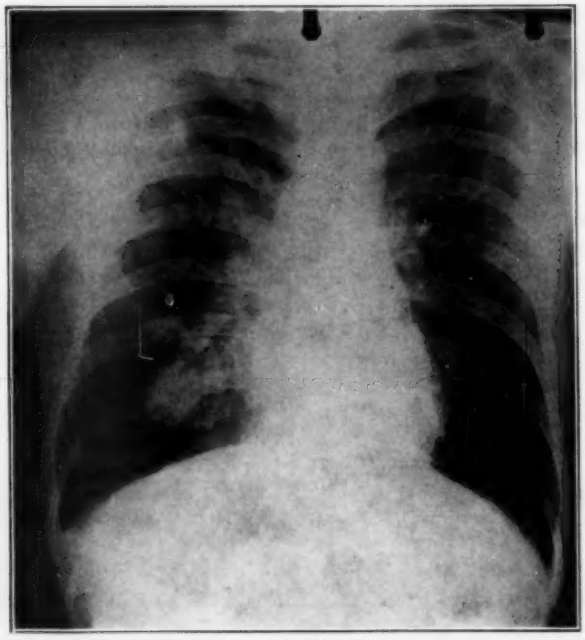

Fig. 3.—Roentgenogram of the patient's chest on first entry. Two shadows with hilar connections are evident.

Fig. 4.—Roentgenogram of the chest (lateral view) on first entry of the patient.

cirsoid purplish mass, about 3 cm. in diameter, in the upper lobe, transmitted a thrill to palpation. The suspected mass in the lower part of the lung could not be visualized. The hilus was exposed without difficulty and the pulmonary artery ligated with silk at two points, about 1 cm. apart, the ends being left long, with the idea of later easy recognition if pneumonectomy should be performed.

After operation the patient coughed up small amounts of bright red blood for several days There was no immediate change in his cyanosis, though this did seem improved while he was in an oxygen tent. There was definite pleural reaction and a small effusion, but thoracentesis did not seem indicated. On December 14, six days after operation, he was up sitting in a chair, and it was thought that his color was improving. On December 18, eight days postoperatively, the red

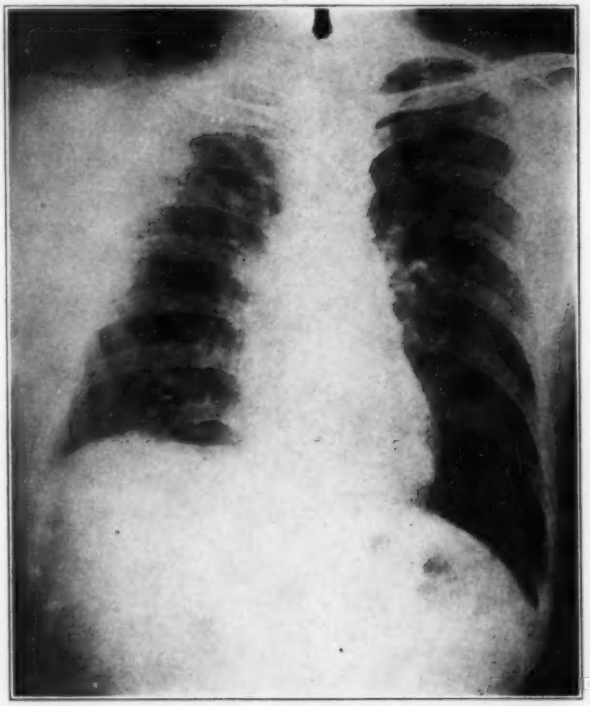

Fig. 5.—Roentgenogram of May 1945. The original shadows are practically gone. There is some pleural thickening.

blood cell count was 5,400,000, the white blood cell count 10,100 and the hemoglobin 16 Gm. His hematocrit reading on December 21 was 51 per cent. He was dismissed from the hospital Jan. 19, 1945, at which time he felt fairly well; there was still some dulness in the right side of the chest; the cyanosis of the finger tips had nearly disappeared, and the blood cell count was within normal limits.

Reexamination of this man on May 29 showed him to weigh 115 pounds (about 52 Kg.), a gain of 10 pounds (about 4.5 Kg.) since he had left the hospital. His color was much improved, and his lips were not so blue as they had been; his fingers were still clubbed, but not nearly so blue as previously. There was a slight contraction of the right side of the chest and not so good expansion as on the left side, with not so good resonance or breath sounds.

The red blood cell count was 6,010,000, the hemoglobin 16.4 Gm., the white blood cell count 9,150, with 58 polymorphonuclear cells, and the hematocrit reading 52 per cent.

The roentgenograms (fig. 5) showed less expansion of the right side of the chest as compared with the left; the right side was not so clear, which suggested pleural thickening, and there was almost complete absence of the previously noted comet shadows.

On Oct. 10, 1947, nearly three years after operation, observations were as follows: There was still a little clubbing of the fingers and slight cyanosis of the nails, with allowances for racial appearance. The patient said that he noticed a change in the color of the blood drawn for tests, as it was now much brighter and

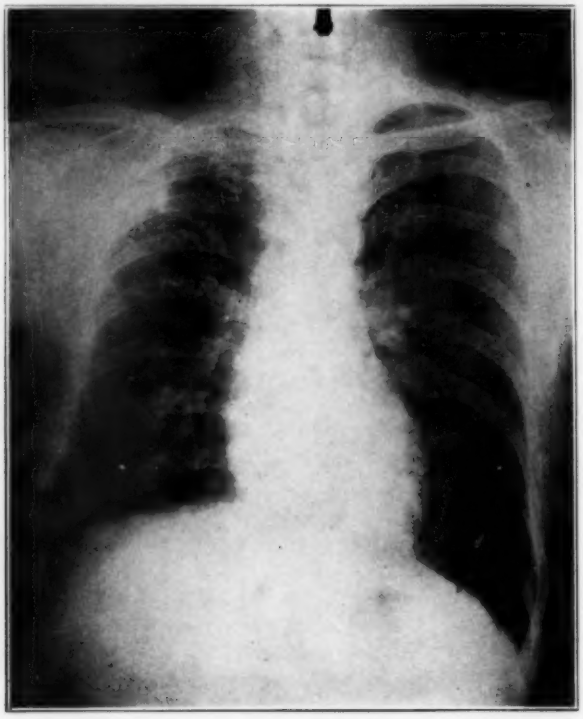

Fig. 6.—Roentgenogram of March 1947. A bare shadow is present at the site of the aneurysm of the lower lobe of the right lung.

redder than before operation. The right side of the chest did not ventilate as well as the left—it lagged on inspiration—and the right side of the diaphragm moved poorly. His general condition appeared to be good. His red blood cell count was 5,380,000, the white blood cell count 5,100, with 46 polymorphonuclear cells, and the hemoglobin 16.5 Gm.

On November 26, he was admitted to the hospital for laboratory observation. The temperature was 97.2 F., pulse rate 80, respirations 20 and blood pressure 88 systolic and 58 diastolic. The urine was normal except for pus cells of 2 plus and cylindric casts of 2 plus. The hemoglobin was 15.2 Gm., the red blood cell count 5,060,000 and the white blood cells 5,600, of which 56 per cent were polymorphonu-

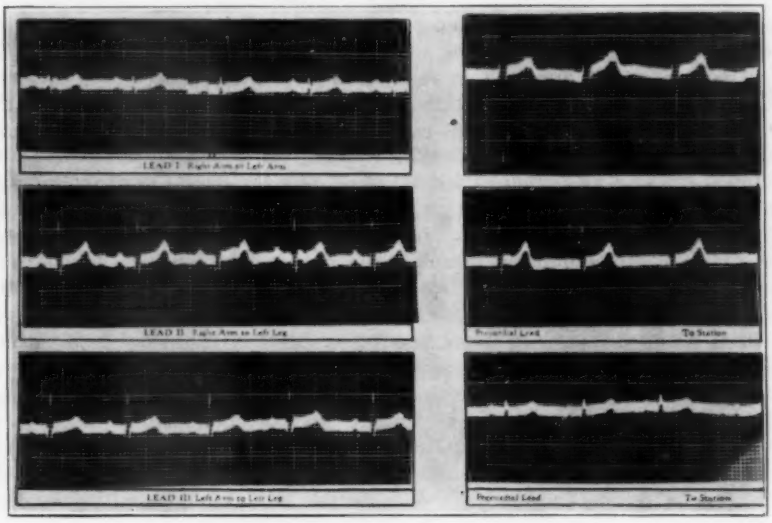

Fig. 7.—Electrocardiogram of Nov. 26, 1947.

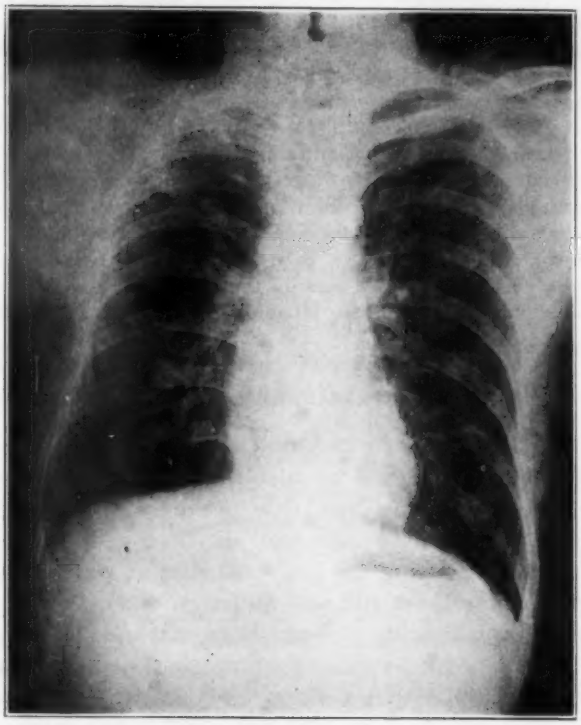

Fig. 8.—Roentgenogram of Nov. 26, 1947. The lower shadow is a little more apparent. The shadow of the upper lobe is not certain.

clear cells, 38 per cent lymphocytes, 5 per cent endothelial cells and 1 per cent osinophils. The hematocrit reading was 48 per cent. The sedimentation rate in thirty minutes was 5 mm. and in sixty minutes 17 mm. Observations of blood gases (Scholander method by Dr. Dalton Jenkins) were as follows: blood from the right femoral artery showed oxygen capacity of 20.00 volumes per hundred cubic centimeters and oxygen content of 16.87 volumes per hundred cubic centimeters, making the oxygen saturation of arterial blood 84.3 per cent. Chemical examination of the blood revealed blood sugar 96, nonprotein nitrogen 38, plasma chlorides 602 (sodium chloride), plasma chloride 102.9 milliequivalents per liter, mean corpuscular hemoglobin 30.04 micromicrograms, mean corpuscular volume 94.9 cubic microns, mean corpuscular hemoglobin concentration 31.7 cc. per hundred cubic centimeters, color index 0.98 and saturation index 0.93.

Roentgenograms showed better ventilation of the right side as compared with that shown in other postoperative roentgenograms. There were still signs of some pleural thickening. The original shadow of the aneurysm in the lower pulmonary field was gone and was replaced by indefinite vascular shadows extending from the root of the lung, shadows which did not have the appearance of the normal vascular tree. The shadow of the aneurysm in the upper right side of the chest was gone, and the shadows to the root of the lung were irregular and ill defined.

The electrocardiogram (fig. 7) was interpreted as follows: The limb leads showed low voltage in the QRS segment of lead I. The P waves no longer showed high voltage. There was slight elevation of the ST segment in lead II. Chest and left leg leads were CF_2, CF_4 and CF_6. There was no diagnostic pattern.

Comment.—At the time of writing, nearly three years had elapsed since ligation of the pulmonary artery. If an arteriovenous shunt was still present in the right lung, it would seem to have been a small one, judging from the observations of the blood. Whether any venous blood at all was being carried to the right lung is not certain, though the viability of the lung was preserved as before by bronchial arterial circulation. It was disquieting to see the faint reappearance of the original shadows, as this might mean a gradual reactivation of the fistulas. If so, a recanalization of the pulmonary artery might have been taking place or the bronchial arterial connections might have been enlarging. So far we have not had the necessary facilities, but we hope in the near future to make bronchospirometric studies separately on the two lungs to see what, if any, aerating function is still present on the right side.

SPECIAL FEATURES OF PULMONARY CIRCULATION

It is an established fact, as emphasized by Holman[20] and many others, that in the peripheral circulation, ligation of the main artery leading to an arteriovenous fistula is absolutely contraindicated, as it will almost always lead to gangrene of the limb. The collateral circulation which was supplying the limb will find its way through the fistula and back to the heart and will no longer work through the distal capillary bed. Even ligation of both the artery and the vein proximal to an arteriovenous fistula in a limb, if employed as a preliminary procedure in the hope that closure may be effected by thrombosis and fibrous contracture, is usually not satisfactory, as the collateral

20. Holman, E.: The Immediate and Late Treatment of an Arteriovenous Fistula, Ann. Surg. **122**:210, 1945.

channels will readily supply blood to the site of decreased resistance provided by the fistula.

We are not prepared to say that these rules have no application in the pulmonary circulation. It has been shown[21] that in a human lung with no fistula the main pulmonary artery may be ligated without danger of gangrene, unless the venous return is obliterated too. Here we have two entirely separate circulations, the bronchial arteries carrying the arterial blood for nutrition, so that no fear of survival need be felt as long as the bronchial circulation is intact. Ligation of the pulmonary vein, however, stops all return circulation and results in hemorrhagic infarction and gangrene. Though the blood volume is nearly doubled in the reported cases of fistula, in only 2 was there cardiac enlargement. The peripheral blood pressure, while low in most cases, showed a diastolic pressure no lower in proportion. The symptoms of dyspnea and faintness would seem due to the low oxygen content of the blood rather than to cardiac weakness.

It is unnecessary to state that the normal circulation of the lungs consists of the blood from the pulmonary arteries, venous in nature, spreading there for oxygenation, and from the bronchial arteries, which are branches of the aorta and are the nutrient arteries of the lung. The return circulation from the lungs is entirely by the pulmonary veins except for some return blood from the hilar region by short bronchial veins. There are no bronchial veins in the lungs except in the hilar region.

The collateral circulation of the lung after ligation of the main pulmonary artery is supplied entirely by the bronchial arteries. It is stated in "Gray's Anatomy"[22] that some of the bronchial arteries "are distributed to the bronchial glands and to the walls of the bronchi and pulmonary vessels, those supplying the bronchi extending as far as the respiratory bronchioles, where they form capillary plexuses which unite with similar plexuses formed by the pulmonary artery, both of which give rise to small venous trunks forming one of the sources of the pulmonary vein."

Guillot, quoted by Miller,[24] after making thirty injections of the systemic and pulmonary vessels stated that he "did not find any evidence that the two systems anastomosed but in every instance communications existed between the bronchial artery and the pulmonary vein."

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21. Rienhoff, W. F., Jr.: The Present Status of the Surgical Treatment of Carcinoma of the Lung, Ann. Surg. **125**:541, 1947.

22. Gray, H.: Anatomy of the Human Body, edited by W. H. Lewis, Philadelphia, Lea & Febiger, 1942, p. 1120.

23. Footnote deleted.

24. Miller, W. S.: The Lung, Springfield, Ill., Charles C Thomas, Publisher, 1937, pp. 82-87.

Miller,[24] after extensive experimental work, stated that it has been proved that anastomoses do not exist between the bronchial and pulmonary arteries. There are, however, anastomoses between the bronchial and pulmonary circulations by means of the capillaries.

It may be pure speculation, but it may be suggested that the capillary combination of the bronchial and pulmonary vessels does not constitute collateral circulation and that the blood in bronchial arteries after ligation of the pulmonary artery does not readily find its way into the low pressure fistula, as it is already in the capillary bed ready to empty into the pulmonary veins.

When a shunt is present, the effective pulmonary flow, it has been pointed out,[13] is decreased. As the parasitic arteriovenous fistula in the peripheral system attracts the greater part of the circulation to it, so does this tendency hold in the pulmonary system. It is reasonable to suppose that in this case, for example, the right lung would present the easier route for blood flow and that in the right lung the easier route would be through the fistulous areas, here again demonstrating the parasitic effect of an arteriovenous fistula and thus lowering the effective pulmonary flow by diverting back into the aorta more than a fair share of unoxygenated blood. It is reasonable to expect that the affected lung receives more of the pulmonary blood than does the other, if one judges by the reports of dilated vessels seen at operation on these fistulous lungs.

On these theories, the ligation of one pulmonary artery may seem justifiable. Bigger[25] mentioned this possibility in the discussion of Jones's[10] case in 1944. All blood is diverted into the good lung, assuring an effective flow to that lung and complete oxygenation. The bronchial artery supply to the fistulous lung is unharmed, allowing proper nutrition and avoiding the dangers and unpleasant sequelae of pneumonectomy. It is not suggested that ligation is the best, or even the proper, treatment in cases of pulmonary arteriovenous fistulas. Treatment must depend in part on the number of fistulas, as these, so far as experience goes, are always multiple and may be in both lungs. It would seem that the treatment of choice, if possible, would be local excision, as demonstrated by Janes,[11] who removed three fistulas in two lungs, in two stages, with complete relief. The second choice would seem to be lobectomy, if the shunts are confined to a lobe, as a lobectomy avoids so many of the serious disadvantages of a pneumonectomy. But if pneumonectomy has to be considered, as it had to be in this case, the results here seem to justify at least preliminary ligation of the pulmonary artery and division in the hope of securing a similar result. Nothing in this operation should interfere with later pneumonectomy, if still indicated, unless later development

25. Bigger, I. A.: Discussion of Case of Pulmonary Arteriovenous Aneurism, J. Thoracic Surg. **13**:357, 1944.

of collaterals should make later operation more difficult. Only experience will show whether, after closure of a large fistula, other small ones will develop and grow to a disabling extent.

SUMMARY AND CONCLUSIONS

The presence of arteriovenous fistula in the lung has been recognized clinically only during the past few years. The steadily increasing number of cases reported suggests that it is much commoner than supposed. The stereotyped syndrome of cyanosis, clubbing of the nails and polycythemia, without abnormality of the heart, is accompanied with roentgenographic observations which are practically diagnostic.

Possible relationship of this condition to hereditary hemorrhagic telangiectasia is indicated, and the incidence of multiple lesions is emphasized.

Consideration is given to the distinctive features of the pulmonary circulation as compared with the systemic circulation, which may permit some variations in treatment of pulmonary arteriovenous fistula as compared with treatment of fistula in the systemic circulation. Apparently arterial connection between the pulmonary artery and bronchial artery branches is hardly to be compared with the free collateral circulation existing in the systemic circulation.

Report is made of one of the early cases in which the condition was recognized and one of the very early ones in which there was surgical treatment. It is known that many more cases, in which the condition has since been recognized and treated, are in the process of being reported. As far as we know, this is the only case in which the condition was treated, and to date beneficially, by simple ligation of the pulmonary artery.

227 Sixteenth Street.

DISCUSSION

DR. J. DEWEY BISGARD, Omaha: I commend Dr. Packard for his presentation of this subject and for the method by which the case was handled.

The ideal to be sought in the treatment in these cases is to obliterate the fistula with conservation of as much functioning pulmonary tissue as possible. As the essayist said, Janes did this in 1 case. The hemangiomas were subpleural and could be locally excised without sacrificing pulmonary tissue. In most cases the lesions are deep, so that it is impossible to obliterate the fistulas by ligation or local excision.

If the lesion is confined to one lobe, a lobectomy, I think, is the procedure of choice, but if the entire lung is involved there is much to recommend ligation of the pulmonary artery, as done by Dr. Packard, rather than a total pneumonectomy.

The result so far speaks for itself, in that Dr. Packard has accomplished obliteration of the fistula, as judged from amelioration of symptoms.

Dr. Packard brought up the question of recanalization, since he ligated the vessel in continuity, and I agree with his recommendation that in subsequent cases the artery be divided. With the pulmonary artery occluded I assume that the lung receives no blood for ventilation and is in reality functionless, but certainly the operation avoids the hazards that are associated with pneumonectomy and the greater rate of mortality.

I have had 1 case. The man was 29 years old. He had had pneumonia eight years before I saw him and since then progressive dyspnea on exertion, nocturnal asthmatic attacks and a dry cough. He had been aware of cyanosis of his finger nails and lips for six years. During the last three years he had had several attacks of loss of consciousness, lasting only a few minutes, frequent headaches, episodes of blurring of vision and chronic fatigue. For one year he had had acute pain just to the right of the sternum, and for three months he had been unable to work on account of fatigue and breathlessness on exertion.

The observations were similar to those in Dr. Packard's case: polycythemia, polyemia and hyperhemoglobinemia, with a hemoglobin content of 18 Gm., 7,000,000 red blood cells, a hematocrit reading of 71 per cent and increased oxygen unsaturation of the blood.

Roentgenographically a comet-shaped lesion, as Dr. Packard has designated it, was seen in the right lung, with two tails extending over to the hilus, representing the vessels leading into this arteriovenous communication. In this area I could hear a continuous murmur, increased on inspiration. This observation, with the presence of a persistent lesion in the lung, which was seen to pulsate fluoroscopically, verified the diagnosis.

It is amazing that this entity was not discovered until nine years ago.

I did a lobectomy for this patient, because the lesion was confined to the right lower lobe. The excised lobe was injected with a barium mixture, through the pulmonary artery, the barium filling the fistula at one point and escaping through the two pipets in the pulmonary veins. Little of the mixture migrated into the vessels to the periphery of the lobe, because a fistula seems to be a way of least resistance.

Prior to operation one could see cyanosis, slight clubbing and telangiectasis of the lips. After operation there was clearing of the cyanosis.

Dr. O. T. Claggett, Rochester, Minn.: I have seen 3 patients with arteriovenous fistula of the lung. I was able to operate on only 1. This was a boy of 17, and I was able to accomplish a cure by excision of the middle lobe.

The condition in this case was different from that in cases reported in the literature elsewhere, in that there was a tremendous collateral circulation with a firm attachment to the thoracic wall. The hilus was easy to manage, but the collateral circulation from the thoracic wall presented a major problem.

The patient was cured, however, and I think, as has been emphasized by Dr. Packard and by Dr. Bisgard, that a lobectomy, when it can be done, is the best treatment. However, in a case such as Dr. Packard had, I certainly would agree that the procedure which he carried out has a great deal of merit.

Dr. George B. Packard, Denver: I want to thank Dr. Bisgard and Dr. Claggett for their discussion. There are just one or two small points I wish to make.

Ligation in continuity is probably wrong. It has been my regret that this pulmonary artery was not divided. I fear that there may be some recanalization of the pulmonary artery, because the oxygen saturation in the arterial blood is now 85 per cent, which means that there must be some unoxygenated blood getting back into the aorta. In a similar situation, one should certainly plan to divide the pulmonary artery.

There is one advantage that might be added. Even if a small fistula or a large fistula is present, because of enlarging bronchial arteries, if the pulmonary artery were completely divided there would be no unoxygenated blood returning to the general circulation.

In particular, I want to state that the study and recognition of this case was entirely the work of Dr. Waring, as was the careful observation during the three years after operation.

RECONSTRUCTION FOLLOWING IRRADIATION INJURIES

PAUL W. GREELEY, M.D.
CHICAGO

THAT injuries follow exposure to radium and roentgen rays has been known for many years. In spite of their known hazards, there are still unfortunate end results. Many of these result as incidental by-products in the necessary treatment of deep-seated malignant conditions. Others arise following overzealous treatment of cutaneous lesions that might well have been treated more judiciously by some surgical procedure. Another type of lesion may be seen following treatment by conscientious physicians who have not been trained properly in administration or who are not aware of the potential hazards involved. On the other hand, severe damage may arise following treatment of a person who is unusually susceptible or from the effect of an x-ray machine that has not been properly calibrated. I have been deeply impressed by the observation of patients who seek plastic surgical repair who received roentgen therapy over forty-five years previously, breakdown and carcinomatous degeneration having occurred after this long interval.[1]

However, in comparison with the vast number of treatments with roentgen rays and radium given, the actual total of injuries is relatively small, but to the plastic surgeon who sees patients with such injuries the number seems to be entirely too large, and, furthermore, these patients comprise an important group because of the discomfort associated with the condition. Because of this, one cannot stress too highly the seriousness of the problem. When irradiation therapy is indicated, it must be given only by an expert.

One still sees roentgen ray dermatitis and necrosis from the "tricho"[1a] system of removal of superfluous hair that was popular

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1. (*a*) Greeley, P. W.: Plastic Repair of Vascular and Pigmented Nevi, Surgery **19**:467-481 (April) 1946. (*b*) Adams, H. D.: Surgical Management of X-Ray Ulceration, Lahey Clin. Bull. **2**:203-206 (Jan.) 1942.

1a. Kaplan, I. I.: Epithelioma of Cheek Developing Fifteen Years After Tricho X-Ray Treatment for Hair on Face, New York State J. Med. **43**:1758-1758 (Sept. 15) 1913.

twenty-five years ago. It is now a well known fact that in killing hair follicles by irradiation incidental permanent cutaneous damage will also occur. In a recent article by Cipollaro and Einhorn,[2] a further warning is stressed.

> A new monster is now lurking around the corner. It is because of this present and future danger that we have prepared this article, not because it is enjoyable to repeat the horror stories of the past which arose from the improper use of x-rays. The harm that was done to girls and young women in the twenties is about to be repeated now in the forties and fifties. It is hoped that the danger can be forestalled and girls and young women can be saved from the agonizing pain suffered by their sisters two decades ago. One can foresee that even boys and young men may be subjected to the same danger, since a patent has been issued for the "X-ray Razor."

The implications in the foregoing warning are obvious and must be given serious thought.

SYMPTOMS

The typical subjective symptoms[3] of chronic roentgen ray dermatitis[4] are severe pain, itching and later ulceration.[1b] Frequently the symptoms are so severe that they produce addiction to the use of morphine, and relief cannot be accomplished until the damaged tissue has been excised. Following surgical excision, the complete relief is dramatic, and permanent cure can be anticipated as soon as the defect created by the surgical excision has been closed.

Of minor symptomatic importance are the atrophy, telangiectasia and some minor contractures of the skin. As with other cutaneous lesions associated with avascularity, chronic ulceration and carcinomatous degeneration are not infrequent.

PATHOLOGIC CHANGES

Irradiation produces typical reactions. The essential observation is obliterative arteritis (fig. 1) or hyalinization of the vessels in the damaged area. This is an irreversible obliterative process that is seen in the arteries, veins, capillaries and lymph vessels and which produces interference in the nutrition of the affected tissues. White necrosis, or anemic gangrene, occurs eventually, which finally results in ulceration. The area is left with poor circulation, which tends to progress with time. A gelatinous membrane develops over the under-

2. Cipollaro, A. C., and Einhorn, M. B.: The Use of X-Rays for the Treatment of Hypertrichosis Is Dangerous, J.A.M.A. **135**:349-353 (Oct. 11) 1947.

3. Bevan, A. D.: Burn of Anal Region, S. Clin., Chicago **1**:1241 (Dec.) 1917; X-Ray Burns, S. Clin. North America **1**:935 (Aug.) 1921; Roentgen Burns of Anus, S. Clin., Chicago **4**:771 (Aug.) 1920. Davis, J. S.: Radical Treatment of X-Ray Burns, Ann. Surg. **72**:224 (Aug. 20) 1919.

4. Rigby, R. A. C., and Mowat, W. J.: X-Ray Dermatitis: Case Report, Brit. M. J. **2**:770 (Nov. 29) 1941.

lying painful ulcer. The surrounding tissues become fibrotic and, if of sufficient magnitude, may extend into the adjacent muscles, tendons and bone (fig. 6*A*). Telangiectasia, pigmentation, atrophy, thickening and keratosis develop in the surrounding skin, the rate of progress being dependent on the degree of endarteritis present. Finally, a certain percentage of lesions degenerate into squamous cell carcinomas. It

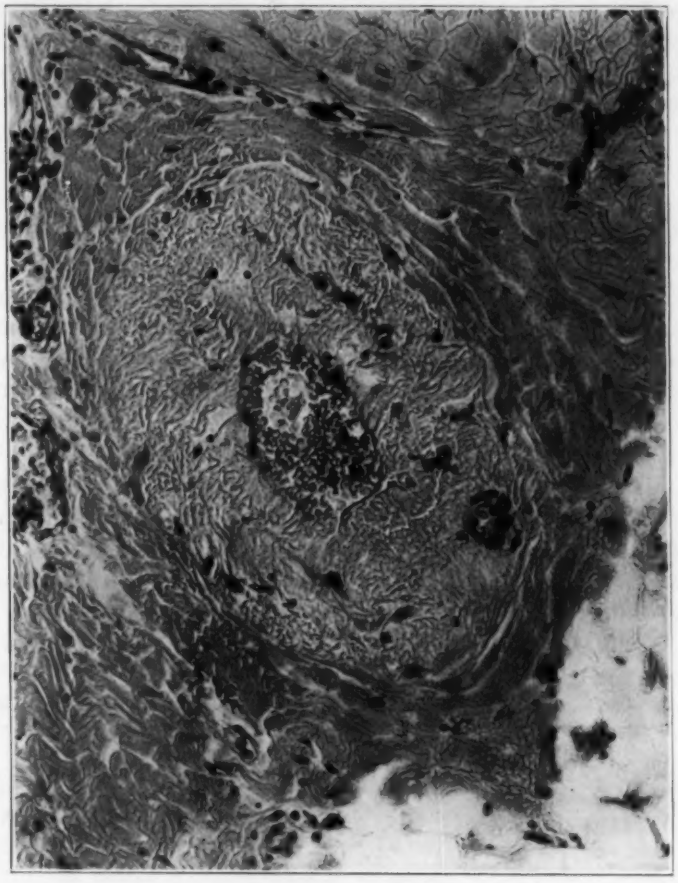

Fig. 1.—High power magnification (×198) of typical section, showing decided thick hyaline fibrous wall. The lumen is reduced to a narrow channel.

is common to see a lesion that resulted from treatment by irradiation for the destruction, for instance, of a basal cell carinoma of the skin. Excessive treatment had caused the area to break down into typical roentgen ray necrosis, and, at a later date, this degenerated into a squamous cell carcinoma. This, obviously, cannot be treated by further irradiation.

TREATMENT

When one considers the avascularity produced during the pathogenesis of an irradiation injury, it becomes apparent that there is little place for conservative management of this lesion. In spite of enthusiastic reports given by the advocates of local applications of radon paste[5] or the aloe vera leaf,[6] I have apparently seen only those patients that did not respond to such simple management. Since the pathologic reaction is progressive and irreversible, I feel that a permanent cure can be anticipated only when all of the damaged tissue has been excised back to an area of good blood supply.[7] If this excision is not wide enough, future reconstructive operations will fail, and later degeneration may occur around or below the site of the original excision. It should be emphasized again that the severe pain and itching are relieved as soon as the damaged tissues have been excised. The remaining problem is one of reconstruction of the cutaneous defect created by the surgical excision.

A few defects may be closed by primary suture after adequate undermining of the border flaps, so that they can be mobilized without tension. The majority of the cutaneous defects will, because of their nature and size, have to be covered by a skin graft or skin flap.[8] The choice of either will be guided largely by the residual blood supply in the surgical defect. Because of its comparative simplicity, a primary split-thickness skin graft[9] may be applied over the area. In certain borderline problems, and this usually entails clinical judgment based on the experience of the operator, the defect is first permitted to fill in with granulations and the split-thickness skin graft is applied to this area when it has been properly prepared (figs. 2 and 3).

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5. Friche, R. E., and Williams, M. M. D.: Radon Ointment for Irradiation Injuries, Proc. Staff Meet., Mayo Clin. **19**:283-288 (May 31) 1944.

6. Wright, C. S.: Aloe Vera Treatment of Ulcers and Telangiectasis, J.A.M.A. **106**:1363-1364 (April 18) 1936. Rowe, T. D.; Lovell, B. K., and Parks, L. M.: Aloe Vera Leaf in Treatment of Third Degree X-Ray Reactions: Further Observations, J. Am. Pharm. A. (Scient. Ed.) **30**:266-269 (Oct.) 1941.

7. Blair, E. C.: Surgical Treatment of X-Ray Burns, J. Radiol. **5**:149-152 (May) 1924. Porter, C. A.: Surgical Treatment of Roentgen Ray Lesions, Am. J. Roentgenol. **13**:31-37 (Jan.) 1925. Cannon, A. B.: Treatment of Burns and Other Superficial Disfigurements, New York State J. Med. **40**:391-399 (March 15) 1940. Davis J. S.: Deep Roentgen Ray Burns, Am. J. Roentgenol. **26**:890-893 (Dec.) 1931.

8. Greeley, P. W.: Plastic Repair of Radiation Ulcers of the Sole, U. S. Nav. M. Bull. **45**:827-830 (Nov.) 1945. Davis, J. S.: Treatment of Roentgen Burns by Excision and Tissue Shifting, J.A.M.A. **86**:1432-1435 (May 8) 1926.

9. Gillies, H. D., and McIndoe, A. H.: Role of Plastic Surgery in Burns Due to Roentgen Rays and Radium, Ann. Surg. **101**:979:996 (April) 1935.

In bases of questionable vascularity, some type of skin flap must be utilized. A previously tubed skin flap taken from a distant point[10] is ordinarily reliable (fig. 4), but entails long tedious operative steps.

Fig. 2.—*A*, roentgen-ray dermatitis of the nose, with necrosis of the upper portion following roentgen therapy for lupus erythematosis. *B*, after excision, a split-thickness skin graft was applied over the exposed perichondrium and periosteum.

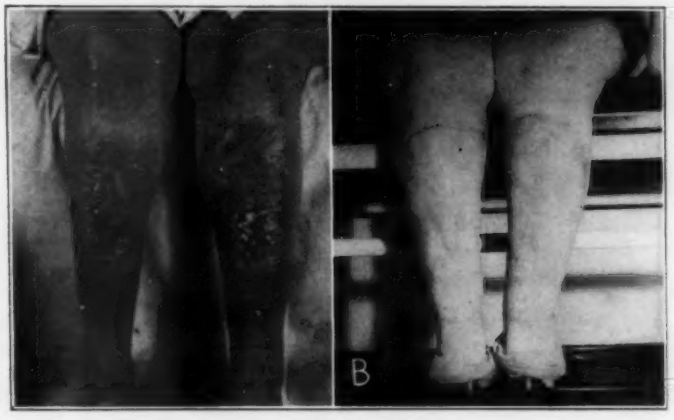

Fig. 3.—*A*, extensive roentgen-ray dermatitis, with ulceration following prolonged treatment for psoriasis. Excision necessitated inclusion of portions of periosteum overlying the tibias. Because of doubtful vascularity of the beds, granulations were first permitted to form. Two weeks later, the areas were covered with split skin grafts. *B*, healed result one year later.

In several cases recently I have been successful in closing these defects with a large direct flap that has been rotated from the border

10. Figi, F. A.: Actinodermatitis (Roentgen Ray Burn) of Entire Neck: Replacement with Tubed Flap from Thorax, S. Clin. North America **12**:947-949 (Aug.) 1932.

of the area (fig. 6). In certain lesions on the face, the donor site has been closed by primary suture, thus giving an ideal cosmetic result with matching face skin. In other areas, where the adjacent skin has been

Fig. 4.—*A*, severe roentgen ray dermatitis, with atrophy, telangiectasia and ectropion of the lower lip following "tricho" therapy for hypertrichosis twenty years previously. Because of anticipated poor vascularity of the bed, a tubed pedicle flap from the upper arm was prepared in advance. When ready for transfer, the damaged tissues were excised and the defect covered with the flap. *B*, condition two years later.

Fig. 5.—*A*, severe roentgen ray necrosis of the skin and the bone of the right half of the nasal arch following treatment of epithelioma, showing the necrotic sequestrum of the frontal process of the maxilla in the wound. *B*, the defect covered with skin-lined forehead flap. *C*, final result. The unused portion of the flap has been returned to the forehead. It should be noted that the forehead flap was chosen because it offered a simple and rapid solution to this patient's problem, since a speedy method was important to him.

relatively inelastic, the donor site has been covered with a split-thickness skin graft (fig. 7). This type of repair has been most satisfactory, because it covers the open wound permanently and quickly with a minimum amount of discomfort or loss of time to the patient.

CONCLUSIONS

1. In spite of present knowledge of roentgen ray and radium therapy, a surprisingly large number of irradiation injuries still occur.

Fig. 6.—*A*, severe roentgen ray dermatitis of the cheek, with ulceration of the central portion of the skin and extensive necrosis of underlying malar-zygomatic bones. This lesion followed the administration of high voltage roentgen therapy (8,000 r) for an epithelioma. The first operation consisted in wide excision of all damaged soft tissues and resection of the major portion of the malar-zygomatic bones. The wound was permitted to fill in with granulations. An open granulating wound 3 inches (about 8 cm.) in diameter was closed three weeks later with a large rotation flap. Wide undermining of the border cutaneous edges permitted closure by primary suture. *B*, completed result.

Fig. 7.—*A*, extensive roentgen ray dermatitis, with necrosis and malignant degeneration of the central portion. This followed high voltage roentgen therapy for a malignant pelvic condition. A large flap was marked out preoperatively on either side of the anticipated defect to follow surgical excision. The lesion was removed down the sacrum. It was then seen that the defect could be closed with a single flap from the patient's left buttock. This flap included the entire subcutaneous fat pad and was transferred without preliminary "delay." The donor area on the left buttock, from which the flap was taken, was covered immediately with a split-thickness skin graft. *B*, early postoperative result. The irregularity of cutaneous levels will fill out spontaneously.

Some result from incidental reactions following treatment of deep lesions, while many others arise in the hands of untrained or inexperienced operators.

2. It must be emphasized that all types of treatments by roentgen rays under disguised names and usually in the hands of lay operators are a serious menace to the public.

3. Roentgen rays produce irreversible reactions that are characterized by severe pain, itching, ulceration and eventual malignant degeneration.

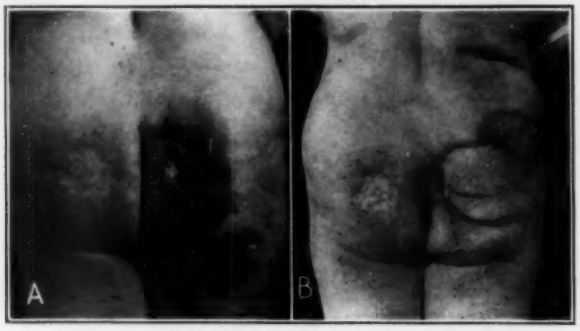

Fig. 8.—*A*, roentgen ray dermatitis of each buttock plus roentgen ray necrosis of the right side. Ischial tuberosity exposed in depths of necrotic area are on the right side. The lesions followed postoperative irradiation for a malignant pelvic condition. The damaged tissue on the right buttock was excised widely and closed with an immediate rotation flap from the border. The donor area was covered by a split skin graft. The area on the left buttock will not be touched unless breakdown occurs or severe symptoms develop. *B*, result after one and a half years.

4. The distressing symptoms of irradiation injuries can be relieved promptly and permanently by wide surgical excision. The resulting defects are then closed by one of several different plastic surgical procedures.

224 South Michigan Boulevard.

DISCUSSION

DR. DOUGLAS MACOMBER, Denver: Dr. Greeley has brought us a valuable message, in calling our attention to the extensive irradiation damage that we who practice this specialty of reconstructive surgery see. Sometimes it makes one become a bit rabid on the subject, and one finds oneself having to exercise control to avoid stating or implying criticism of colleagues for such treatment.

Unfortunately, this damage is not all ancient; some of it is still occurring. One sees many lesions which are not radiosensitive, such as certain of the melanomas, sarcomas and some of the hemangiomas, treated in this manner. It brings individual surgeons and the profession a great deal of adverse criticism.

The discouraging thing about it, too, is that sometimes one thinks that all of the damaged tissue has been removed, only to discover that this has not been done. Some of the overirradiated tissue shows nothing for fifteen or twenty years and then becomes malignant a bit at a time. Meanwhile, many of the lesions ulcerate and become exquisitely sensitive.

The most damage one sees, I am sure, is from the multiple small doses given over long periods of time. One sees that the men who practice the specialty of

radiology are more likely to decide in the first place whether a defect is radiosensitive and then to figure out a lethal dose or two and give it. However, in some of the other specialties, in which irradiation is used, treatment is carried out over long periods of time.

A few years ago, when I had not long practiced in this specialty, I had seen enough cases of irradiation dermatitis and necrosis to provide an educational exhibit for the state society meeting. On looking at the lesions, many of which were on the face, I thought that a number of my older colleagues would recognize some of their patients and would not thank this "young upstart" for presenting them before the profession. Therefore, I asked one of these colleagues whether he thought that I should withhold the exhibit a few years. He said, "Indeed you should. I believe that you would end up with more friends if you keep silent in this matter." To my way of thinking, one should not remain silent. One should say more about it and make oneself heard in defense of professional reputation and the patients' welfare.

DR. PAUL W. GREELEY, Chicago: I want to thank Dr. Macomber for his words. I do not believe that the radiologists are the only ones that should be criticized. I think that sometimes the responsibility belongs to the surgeons. The reason I say this is that the actual primary excision of many of these small cutaneous lesions is not difficult, but many surgeons are discouraged by the fact that they will be faced with an open wound that might be 1 inch (about 2.5 cm.) in diameter or it might be 6 inches (about 15 cm.) or more in diameter, any they wonder what they will to do with it.

Most of these things resolve around the problem of wound closure. I feel that any of you who become adept in these procedures can manage the initial treatment of these lesions much more safely than can be done when excessive radium or roentgen ray therapy becomes necessary to effect a cure.

I was not trying to preach a sermon in the early part of this presentation, but I wanted you to know that there are certain distinctive reactions occurring that I do not believe that all of you see every day, and I wished to bring them to your attention. I feel it is time to think about these things seriously, so that when one has a patient with a problem of this type, one will consider whether the lesion should be treated surgically or by roentgen rays or radium.

If each of you, as surgeons, will evaluate your problems individually, you can then decide more accurately how each patient should be approached when the final result to the patient is visualized.

SURGICAL REPAIR OF CLEFT LIPS

JAMES BARRETT BROWN, M.D.
AND
FRANK McDOWELL, M.D.
ST. LOUIS

CLEFTS of the lip and palate constitute the most frequent serious congenital deformity amenable to surgical treatment. One baby in every 665 is born with a cleft lip or cleft palate, or both, and involved in each one of these misfortunes is a person who needs surgical help as much as any one possibly could. These lesions are not becoming less frequent, but, possibly as a result of plastic operation, many patients with good repairs are getting by without attracting attention.

It is evident, however, that one cannot give the patient all that he deserves, and this makes it necessary that all technical advances be utilized. Two advances of recent years are: (1) the development of a method of marking which insures the most symmetric nostrils that it is now possible to obtain and (2) the realization of the extreme importance of having a full, smooth, lower border in the repaired lip, which is not only farther forward than the lower lip but is also actually out in front of the rest of the upper lip. The latter is obtained by an operative design which puts an extra flap of tissue into and across the lower border of the repaired lip.

The easiest method of repair for a single cleft lip is the V-excision operation, which consists of just cutting a slice of tissue off each border of the cleft and approximating the raw edges. Though various recent and modern names have been attached to this operation, it was used by Celsus, the ancient Arabian physicians and the medieval barber surgeons and has been the procedure employed by most surgeons during the last two thousand years. During all of this time the chief stigmas of the repaired total cleft lip have been: (1) the flared slumped nostril and (2) a lack of tissue at the lower border, as evidenced by either (*a*) a "whistling" deformity or (*b*) a tight retruded vermilion border.

The two improvements outlined in this paper were designed to prevent these common stigmas. The details of their surgical execution

Read at the Fifty-Fifth Annual Meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 4, 1947.

were illustrated and discussed in a recent paper,[1] so that this paper will be limited to some of the more essential and salient points.

DESIGN FOR OBTAINING SYMMETRICAL NOSTRILS

The newborn baby with a wide open cleft has a columella which slants toward the opposite side and a horizontal bridge of nasal tissue present where a tubular nostril should be. The repair of the nose is as important as the closure of the lip. It should include straightening of the columella, getting it in the midline and rolling this straight bridge of nasal tissue up into a tubular nostril with the base of the

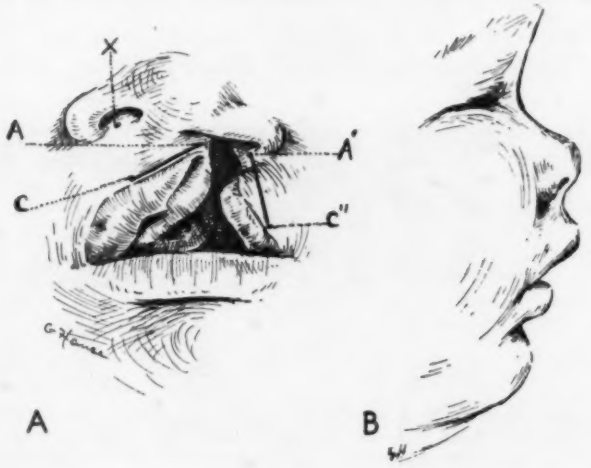

Fig. 1.—*A*, marking for the old classic, "V-excision" operation. Many good results have been produced by this, particularly in little partial clefts, but it fails to put an additional amount of tissue in the lower border of the lip. It should be noted that this method is not recommended. *B*, drawing of profile of a normal infant, showing the forward curve of the upper lip from above downward and the position of it with regard to the lower lip.

ala pointing in toward the columella instead of straight backward into the face.

It is of help in doing this first to mark out symmetric points in the two nostril floors with a mechanical drawing pen and 5 per cent alcoholic methylene blue. To do this, the columellar side of the lip is pulled and rotated over into the cleft until the columella is straight and in the midline. While held there, an imaginary line is visualized crossing the upper border of the lip horizontally at the level of the base of the columella. The point at which this line transects the mu-

1. Brown, J. B., and McDowell, F.: Simplified Design for Repair of Single Cleft Lips, Surg., Gynec. & Obst. **80**:12, 1945.

cocutaneous junction near the cleft is point *A* (fig. 1*A*); point *X* is in the same relationship to the columella in the normal nostril floor (figs. 1 and 2).

The relationship of *X* to the base of the normal ala is noted and point *A'* is made in the same relationship to the ala on the cleft side. After wide undermining of the lip, cheeks and lower part of the nose, *A* is approximated to *A'* (fig. 2).

The design insures equality of the two nostril floors, the same level for the two nostrils and symmetric placement of the bases of the two alae in relationship to the columella. It is important to obtain these results at the primary operation, as otherwise it will be necessary to take the entire lip apart and attain these objectives at a secondary operation.

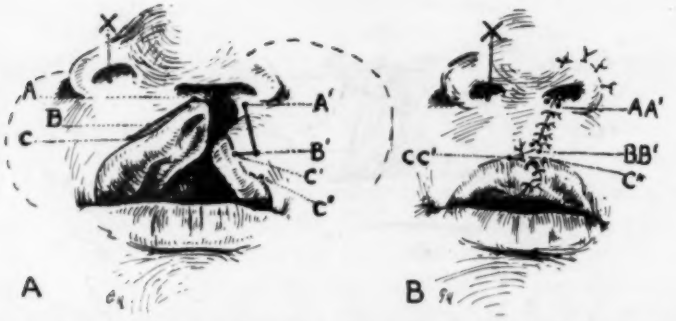

Fig. 2.—Drawings showing the design for, and closure of, a single cleft lip by the flap operation. This saves tissue which would be thrown away in the V-excision operation and puts it down in the lower border of the lip, where it is most needed to produce a forward thrust.

FLAP OPERATION FOR EXTRA TISSUE AT THE LOWER BORDER OF THE LIP

The usual total single cleft of the lip is decidedly deficient in tissue at the lower border on the columellar side (figs. 1*A*, 2*A* and 3*A*). In the old V-excision operation, tissue is thrown away at the lower border of the lip on the alar side, which could be used to fill in the deficient area on the columellar side. In the flap operation, a triangular full thickness segment of lip is saved at the bottom of the lip on the alar side and fitted across the cleft into the deficient area at the bottom of the lip on the columellar side. This can readily be seen by studying the marking plans, in which the V-excision operation is marked out first (fig. 1*A*) and then the flap is designed (fig. 2*A*).

After wide undermining, the lines *ABC* and *A'B'C'* are incisively cut with a knife and the two edges of the lip are accurately mortised together approximately *AA'*, *BB'* and *CC'*. In doing this, the surgeon operates as though he were working in wood, rather than in rub-

ber, and no attempt should be made to stretch the tissues to make them fit. The inside mucosal suturing should be just as accurate as that on the outside and carried high up into the fornix.

This design avoids any straight line scar closure which might contract and later produce a "whistling" deformity, and interdigitation of small zigzag flaps of vermilion tissue (fig. 2*B*) still further prevents this. However, the provision of the extra flap of tissue where it is most needed is important. The looseness, fulness and "forward thrust" of the lower edge is what makes these lips look normal (fig. 3).

DEVELOPMENT OF TECHNICS

Surgery for cleft lips has shared in the developments common to all surgical practice, such as developments in anesthesia, asepsis, chemotherapy, prevention and treatment of shock, precision instruments and improved methods of wound closure. These have sometimes been mistaken for improvements in the operation itself, so that the common deformities resulting from the historical operation have persisted to the present day.

Fig. 3.—*A*, picture of an infant, showing the deficiency in tissue at the lower border on the columellar side. *B* and *C*, result of closure of a wide single cleft by the flap operation, showing the front view and the forward thrust of the lower border of the lip in profile.

It is also unfortunate that cleft lip so frequently coexists with cleft palate, causing many surgeons to be preoccupied with closing part of the palate at the same time that the lip is closed. Aside from the probability that early surgical treatment of the palate may result in unnecessary dental damage, it seems to us that good repair of the lip is difficult enough to require the surgeon's undivided attention in the process.

The improvements noted in this paper are a long slow process contributed to by many persons, so that it is difficult to assign proper

credit in each instance. Mirault of Algiers, while attempting to close a total cleft by Malgaigne's variation of Nélaton's operation for partial clefts, turned down tiny vermilion flaps from either side of the cleft and then cut one of them off when he approximated the edges. The woodcuts in his original article (1844) were so poor, and even reversed by the engraver, that it is almost impossible to tell which flap he used (all of his description is in terms of "right" and "left"). Whether he used a full thickness lip flap at all is doubtful, and in 1871 he published another paper in which he used only a small flap of vermilion tissue from the columellar side. However, his original operation was sketched in Henry Hollingsworth-Smith's book (1852)

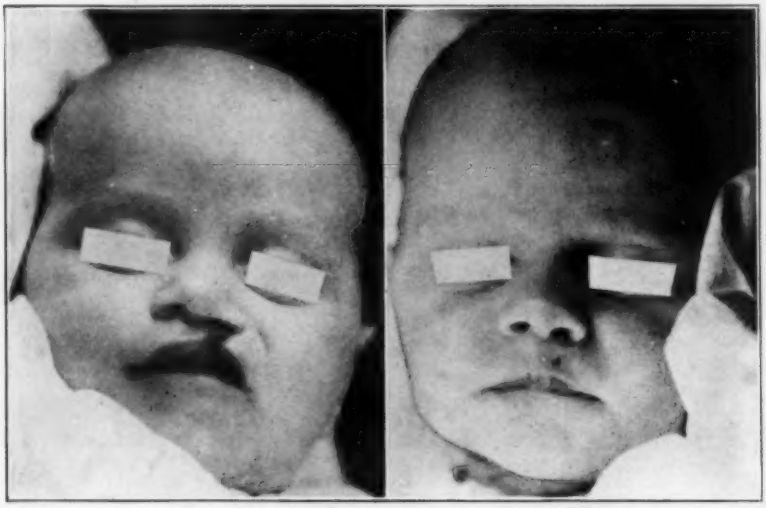

Fig. 4.—While partial cleft lips can be successfully closed by the V-excision operation, even better results can often be obtained by the flap operation, as shown here.

in such a manner that it appeared that a full thickness flap was being used. In successive reproductions in various articles and books during the next decades, the flap grew larger and larger, until it was depicted as about half the length of the lip in Kolle's book (1911), but it was nearly always shown for partial clefts. Interest in this operation was revived about twenty years ago,[2] but the flap described then was half the length of the lip and has since proved to be too large. However, the idea of having extra tissue to fit in the lower border of the cleft on the columellar side is just as desirable as ever, whether Mirault recognized it or not (fig. 4).

2. Blair, V. P., and Brown, J. B.: Mirault's Operation for Single Harelip, Surg., Gynec. & Obst. **51**:81, 1930.

LATE OPERATIONS FOR IMPROVEMENT

Double clefts are about twice as difficult to repair, and the results are only about half as good. No presently known operation is entirely satisfactory for these, but the same plan of using a small flap from the cleft edge on either side seems to be the best one at the present time[3] (fig. 5). Various plans have been proposed to use the vermilion tissue of the central segment in the final repair, but it curves in the wrong direction and tends to produce a double notch, so that we think that it is best to turn it back and use it for extra lining.

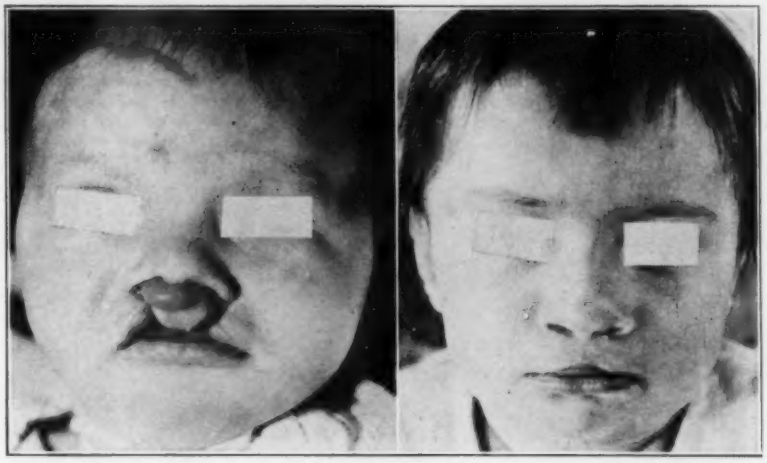

Fig. 5.—Result of early closure of total double cleft lip by the flap operation, with the flaps brought from the two sides together in the midline beneath the prolabium.

LATE OPERATIONS FOR IMPROVEMENT

Late operations are of tremendous importance and should be done in greater numbers than they are to correct any deformity remaining from the primary repair or one which develops during growth.[4] Most of these deformities can be secondarily corrected by local readjustment of tissues, which often means taking the lip apart and reconstructing it by the same design just outlined for primary repairs (fig. 6). The secondary repair of the nose is just as important as repair of the lip and frequently requires an osteoplastic operation.

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3. Brown, J. B.; McDowell, F., and Byars, L. T.: Double Clefts of the Lip, Surg., Gynec. & Obst. **85**:20, 1947.

4. Brown, J. B., and McDowell, F.: Secondary Repair of Cleft Lips and Their Nasal Deformities, Ann. Surg. **114**:101, 1941.

Fig. 6.—Late secondary repair, in which the lip and nostril were completely reconstructed by the method outlined in this paper. These secondary operations are often the most worth while of all and should be done in greater numbers.

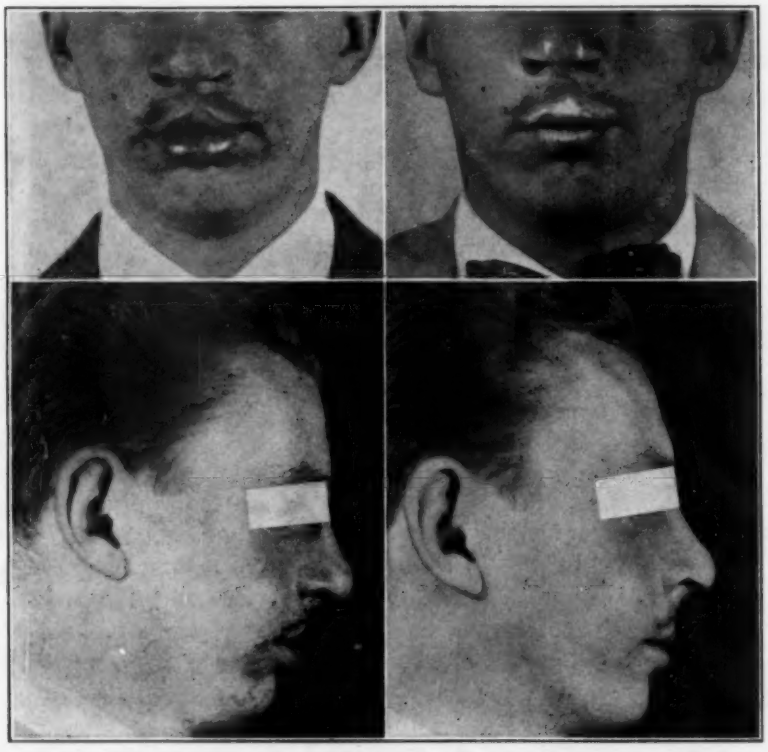

Fig. 7.—Reconstruction of total double cleft lip by the use of a lower lip flap to restore the normal balance between the middle and lower thirds of the face. The postoperative photographs were taken early after operation, while the scars were still red and visible.

Flaps of the Lower Lip.—Flaps of the lower lip are a fundamental requirement in many of these patients to provide enough tissue in the upper lip to get it out in front of the lower one (fig. 7). This operation is almost specific for restoring balance between the two lips when too much tissue has been sacrificed at the primary operation. The flap is designed to put more tissue in the lower part of the upper lip, thus recreating the forward thrust, but the tail end of the flap can be run up into either or both nostril floors when tissue is needed in those areas. The flap may need some fine readjustments when in place; supporting dental prosthesis may be required, and concomitant osteoplastic operations on the nose are often of value.

Cartilage Transplants to the Nose.—Cartilage transplants to the nose are frequently indicated when insufficient nasal support is present, especially in patients who have had double clefts.

COMMENT

There is little reason for any one's having to go through life with any deformities which can be corrected or improved, and persons with such deformities deserve all possible surgical help.

There are many different opinions about the finer points of technic, but there is agreement that the work must start with an adequate patient-physician relationship, especially through the reconstructive period. Technic is constantly changing, but this primary personal relationship must remain to produce best results.

Persons with cleft lips vary in mentality, ability and personality, as much as do other persons, but, because of their handicap, they often tend to work harder both in school and in later life. For this reason, persons with good repairs often stand high in their classes at school and frequently become outstanding in professional and business life. Few other operations can so decidedly influence a patient's entire career and be so gratifying to the surgeon when a successful result is obtained.

INDICATIONS FOR AND ADVANTAGES OF SCHOEMAKER-BILLROTH I GASTRIC RESECTION

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THE SURGICAL procedure which we shall consider is not a new one. In 1881 the first successful gastric resection ever performed was carried out by Billroth, who used a rather similar technic. The Billroth I operation, as it has been called since its original description, has had varying degrees of favor. In general, the Billroth II procedure, the Polya types of gastric resection and their innumerable modifications have been used more extensively than the Billroth I procedure, and a review of the literature on gastric resection has convinced us that the Billroth I procedure has been performed only rarely in most surgical clinics in the last twenty years.

Some of the great surgeons of the past were well aware of the advantages of the Billroth I type of gastric resection. Haberer,[1] Finney,[2] Mayo[3] and Schoemaker[4] developed their own modifications of the original operation and used them extensively.

After we had submitted our title for this paper, we found, on reviewing the literature, that W. Mayo[3] had read a paper on this subject at a meeting of the Surgical Association in December 1922, just twenty-five years ago. We would like to repeat some statements that Mayo made in that paper, because at that time he pointed out a number of the advantages of and indications for the Billroth I type of operation that we wish to reemphasize at this time. Mayo said[3]:

From the Division of Surgery, Mayo Clinic.

Read at the Fifty-Fifth Annual Meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 6, 1947.

1. Haberer, H.: Terminolaterale Gastroduodenostomie bei der Resektionsmethode nach Billroth I, Zentralbl. f. Chir. **49**:1321-1326 (Sept. 9) 1922.

2. Finney, J. M. T.: A New Method of Gastro-Duodenostomy, End-to-Side; with Illustrations, Tr. South. S. A. **36**:576-578, 1923.

3. Mayo, W. J.: Radical Operations on the Stomach with Especial Reference to Mobilization of the Lesser Curvature, Surg., Gynec. & Obst. **36**:447-453 (April) 1923.

4. Schoemaker: Zur Technik der Magenresektion nach Billroth I, Arch, f. klin. Chir. **121**:268-271, 1922.

In the Clinic, following the removal of the malignant portion of the stomach, we are more and more inclined in favorable cases to restore the lumen by anastomosing the end of the duodenum to the narrowed end of the stomach after the Billroth I method. This operation should not be forced. If it cannot be done easily, one of the other methods of gastrectomy should be applied. Narrowing of the stomach may be accomplished on the lesser curvature by dissecting out the necessary portion of the lesser curvature and suturing behind as the tissues are divided in front. The Billroth I operation is again coming to the front, not only for cancers located in the plyoric end of the stomach, but also for any ulcers of the lesser curvature. Instead of removing an unnecessarily large area of the stomach, as in the other forms of partial gastrectomy, it removes the disease, saves the normal stomach and restores the gastro-intestinal canal by uniting duodenum to the amputated end of the stomach. In certain persons the shape, position and movability of the stomach together with its loose attachments have made it comparatively easy to remove the pyloric half of the stomach and still directly anastomose the end of the gastric stump to the duodenum . . . . Schoemaker was the first to free himself entirely from the Billroth I prejudice. He recognized fully that the fatal suture angle did not occur under modern technic and showed that extensive removal of the stomach with sufficient of the pyloric end to accomplish the purpose of the operation would in a considerable percentage of cases enable direct union between the cut end of the stomach and the duodenum.

A few years ago we recognized the advantages of this procedure and decided to use it in cases of gastric lesions in which it appeared feasible. The modification of the original Billroth I operation that we have used is essentially that of Schoemaker. It should be pointed out, however, that it does not differ much from the modifications described by Billroth and by Mayo except that it accomplishes a more extensive resection, particularly along the lesser curvature. During the last five years we have performed this operation in 183 cases, and our enthusiasm for the advantages of this procedure have grown with our experience. In our opinion the advantages of this type of gastric resection are not appreciated generally at the present time, and we believe that it should be used more frequently than it has been in recent years.

We recently have reviewed the records of the 183 patients mentioned previously. What we believe to be the indications for the Billroth I type of gastric resection can be indicated best by reviewing this series. One hundred and forty-two of the patients were men, and 41 were women. Their ages ranged from 27 to 89 years. Two thirds of the patients were more than 50 years of age. Table I indicates the primary lesions for which the operation was performed. As would be expected, most of these operations were performed for lesions of the stomach which did not involve the duodenum. Gastric resection with gastroduodenal anastomosis requires a mobile and relatively normal duodenum. Only occasionally can this operation be used in cases of duodenal ulcer. In such cases, fixation, shortening and narrowing of the duodenum usually will not permit a safe and satisfactory restoration of gastroduodenal continuity after gastric resection. A Billroth I

resection can often be used to good advantage in cases of gastrojejunal ulcer, because in many of these cases the original duodenal ulcer has healed and the duodenum is practically normal again. If the condition of the duodenum will permit it, we believe that a Billroth I resection is the surgical treatment of choice for duodenal and gastrojejunal ulcers. A Billroth I resection of three fifths or three fourths of the stomach and the pyloric ring will reduce the gastric acidity as effectively as any other type of resection of equal extent and will have additional advantages over gastrojejunal anastomosis. First, it can be performed more quickly and more easily; second, closure of the duodenal stump, the most vulnerable point in any gastric resection, is avoided; third, the duodenum has greater resistance to formation of ulcer than the jejunum, and, fourth, a closer to normal gastrointestinal function will result.

TABLE 1.—*Lesions for Which Gastric Resection Was Performed*

Lesions	Cases
Gastric ulcer	72
Gastric carcinoma	72
Gastrojejunal ulcer	18
Duodenal ulcer	10
Chronic gastritis	4
Gastric polyps	2
Lymphosarcoma	2
Leiomyoma	1
Gastric cyst	1
Gastrojejunocolic fistula	1
Total	183

It has been argued that it is not possible to perform gastric resection and still restore gastroduodenal continuity in cases in which ulcers are situated high in the stomach or in cases of extensive malignant lesions of the stomach. This has not been our experience. Since we have used this operation, we have not seen a benign gastric ulcer that was too high to permit this operation. Even ulcers situated at the esophagogastric junction on the lesser curvature have been removed without difficulty. Many gastric carcinomas can be removed by this procedure. The entire omentum and all of the regional lymph nodes can be removed as adequately as they can with any other type of gastric resection. It is possible to excise as much of the stomach as necessary around the growth itself and still restore gastroduodenal continuity in most cases, unless total gastrectomy is necessary. We

recently have performed total gastrectomy and esophagoduodenostomy in 3 cases.

A comparison of results obtained with the Billroth I type of gastric resection and other types of gastric resection in the treatment of carcinoma of the stomach can be found in Walters, Gray and Priestley's book.[5] Their statistics cover the experience of the Mayo Clinic with

TABLE 2.—*Carcinoma of the Stomach: Rates of Survival of Five Years or More According to Type of Operation**

Type of Operation	Patients Who Survived Operation		Lived Five or More Years After Operation	
	Total	Traced	Number	Percent of Traced Patients
Billroth I	136	135	47	35
Billroth II	358	356	100	28
Anterior Polya	485	479	119	25
Posterior Polya	808	802	232	29
Segmental resection	68	68	21	31
Local excision	107	105	45	43
Partial resection	1,962	1,945	564	29
Total gastrectomy	6	6		
Resection, total	1,968	1,951	564	29

*Modified from Walters, Gray and Priestley.[5]

TABLE 3.—*Carcinoma of the Stomach: Hospital Mortality According to Type of Operation**

Operation	Patients	Hospital Deaths	
		Number	Percentage
Billroth I	170	19	11.2
Billroth II	437	77	17.6
Anterior Polya	659	117	17.8
Posterior Polya	1,264	192	15.2
Segmental resection	87	14	16.1
Local excision	128	13	10.2
Total gastrectomy	27	18	66.7

*From Walters, Gray and Priestley.[5]

this disease from 1907 to 1938 (tables 2 and 3). The hospital mortality for the Billroth I operation was 11.2 per cent, as compared with 17.6 per cent for the Billroth II operation, 17.8 per cent for the anterior Polya operation and 15.2 per cent for the posterior Polya operation. The rate of survival of five years or more for the Billroth I operation

5. Walters, W.; Gray, H. K., and Priestley, J. T.: Carcinoma and Other Malignant Lesions of the Stomach, Philadelphia, W. B. Saunders Company, 1942.

was 35 per cent, as compared with 28 per cent for the Billroth II operation, 25 per cent for the anterior Polya operation and 29 per cent for the posterior Polya operation. These differences are significant.

The extent of the resection in this series has been measured in two ways: (1) by the surgeon's estimate of the portion of the stomach

TABLE 4.—*Extent of Resection*

Portion of Stomach Excised*	Cases
One third	8
One half	48
Three fifths	75
Three fourths	38
More than three fourths	14
Measurement in centimeters of portion excised between greater and lesser curvature†	**Cases**
10 to 14	86
15 to 19	91
20 to 25	6

*As estimated by the surgeon.
†As determined by the pathologist.

TABLE 5.—*Postoperative Complications*

Complications	Cases	Deaths
Infected wounds (minor)	16	
Phlebitis	2	
Pulmonary embolus	3	
Postoperative atelectasis	3	
Bronchopneumonia	5	
Leak of anastomosis (slight)	4	
Separation of anastomosis with peritonitis	2	2
Coronary occlusion	1	1
Cerebrovascular accident	1	1
Alkalosis (cause unknown)	1	1*

*Patient died thirty days after operation.

that was excised and (2) by the pathologist's measurements made midway between the greater and lesser curvature (table 4). According to the surgeon's estimate, three fifths or more of the stomach was resected in 127 cases, or 69.4 per cent. By the pathologist's measurements 15 cm. or more of stomach was resected in 97 cases, or 53 per cent. We are convinced that an adequate gastric resection can be performed.

Much has been said about the danger of leakage at the point where the closed portion of the lesser curvature and the portion of the remainder of the stomach which has been anastomosed to the duodenum come together. This danger has been greatly exaggerated. In 4 cases, a slight amount of leakage occurred for a few days but healing then occurred without incident (table 5). In 2 additional cases, separation of the anastomosis occurred and peritonitis developed and caused death. In 1 of these cases, about seven eighths of the stomach was excised because of the presence of carcinoma. The patient had complete obstruction of the outlet of the stomach, had lost 60 pounds (27.2 Kg.) and was a poor candidate for any operation. In the other case leakage occurred after resection for duodenal ulcer. As mentioned previously, the operation cannot often be used in cases of duodenal ulcer, because of the presence of induration around the duodenum in these cases. Such reaction was probably responsible for failure of healing to occur in the second case. With proper selection of patients and careful technic, there is little danger of leakage.

One would expect more gastric retention after a gastroduodenal anastomosis than after the wide gastrojejunostomy common to most gastric resections. In our series of cases, gastric aspiration was not used routinely after operation. In 19 cases (10 per cent), gastric retention which was associated with vomiting or required gastric aspiration occurred for from one to twelve days. This rentention disappeared without difficulty or complication. In 6 additional cases, gastric retention necessitated a second operation. There were no deaths from this complication.

Other complications that occurred are indicated in table 5. There were 5 deaths in the series, a mortality rate of 2.7 per cent. Three of these deaths occurred in cases of carcinoma, 1 in a case of duodenal ulcer and 1 in a case of gastric ulcer.

In reviewing this series of cases, it was interesting to note the number of instances in which other major surgical procedures were performed at the same time as the gastric resection. Table 6 indicates these coincidental major surgical procedures. It is worth mentioning that there were no deaths in the group of cases in which other operations were performed.

We shall not attempt to describe in any detail the technic of the procedure we have used, but it should be mentioned that one of us (J. M. W.) has used a closed aseptic type of anastomosis and one of us (O. T. C.) has used an open type of anastomosis. The operations performed in this series have been equally divided between us, and our experiences and results have been similar. The complications that have occurred in each group have been almost identical. From a tech-

nical standpoint, we would like to emphasize the importance of limiting this operation to those cases in which there is a suitable duodenum. As W. Mayo said, this procedure should not be forced. Tension on the anastomosis, even after extensive resection, can be avoided by mobilizing the stomach far up along both the lesser and the greater curvature and by mobilizing the duodenum by freeing it from its lateral peritoneal attachment.

Some of the advantages that we believe are offered by the modified Billroth I type of gastric resection are as follows:

1. It is the quickest and easiest type of partial gastric resection that can be performed.

TABLE 6.—*Other Operations Performed With Gastric Resection*

Operations	Cases
Disconnecting of gastroenteric anastomosis and closure of jejunum	16
Disconnecting of gastroenteric anastomosis, closure of colon and jejunum and splenectomy	1
Disconnecting of gastroenteric anastomosis, closure of jejunum, cholecystectomy, choledocholithotomy and repair of ventral hernia	1
Disconnecting of gastroenteric anastomosis and splenectomy	1
Splenectomy and partial pancreatectomy	4
Splenectomy	3
Splenectomy and partial hepatectomy	1
Cholecystectomy	7
Repair of ventral hernia	3
Appendectomy	5
Excision of Meckel's diverticulum	1
Repair of epigastric hernia	2
Jejunostomy	3

2. It avoids the additional steps of duodenal closure and disturbance of the colon and mesocolon necessary in the more commonly performed gastric resections.

3. It accomplishes the objectives of gastric resection with a minimum of surgical trauma and handling of tissue.

4. It is a safe operation when used according to the indications mentioned previously.

5. It is a physiologic operation, because it restores normal gastroduodenal continuity, That this is desirable can hardly be questioned.

Wollaeger, Comfort, Weir and Osterberg[6] have made careful nutri-

6. Wollaeger, E. E.; Comfort, M. W.; Weir, J. F., and Osterberg, A. E.: The Total Solids, Fat and Nitrogen in the Feces: II. A Study of Persons Who Had Undergone Partial Gastrectomy with Anastomosis of the Entire Cut End of the Stomach and the Jejunum (Polya Anastomosis), Gastroenterology **6**:93-104 (Feb.) 1946.

tional and functional studies on patients who had undergone various types of gastric resection. Although their studies are not complete as yet, their results so far indicate that in cases in which a Polya type of resection has been performed, by anastomosing the full end of the stomach to the side of the jejunum, the patients are more likely to have digestive disturbances, such as the "dumping syndrome," than are patients who have undergone a Billroth I type of resection, even though the amount of stomach excised is the same. In addition, patients who have undergone a Polya type of resection lose more fat and nitrogen in their feces than do patients who have undergone a modified Billroth I operation. Some of the more important factors which they considered accountable for the poorer clinical results of the Polya type of resection are: (1) rapid emptying of the stomach, (2) intestinal hurry, (3) diminished flow of pancreatic secretions and bile, because of impairment of the mechanism of such flow, and (4) imperfect mixing of food with digestive ferments, because of shunting of gastric contents away from the duodenum. Their observations confirm our clinical impressions that patients who have undergone a Billroth I type of operation have less trouble with digestion, intestinal motility and nutrition than do patients who have undergone any other type of gastric resection.

The chief contraindications to the use of the Billroth I resection for lesions that require gastric resection involve the duodenum. Fixation, shortening, narrowing or induration of the duodenum will prevent the establishment of a safe and satisfactory anastomosis. In most other circumstances, the Schoemaker modification of the Billroth I operation provides a means of gastric resection that offers many advantages over the more commonly performed types of gastric resection.

INTRACRANIAL PNEUMOCEPHALUS

Report of a Case

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INTRACRANIAL pneumocephalus (also termed intracranial pneumatocele or aerocele) is an abnormal collection of air within the skull. The term also includes gas formed by putrefactive bacterial infections within the skull, such as occurs in certain abscesses of the brain. The condition is infrequent, but it is not as rare as the number of cases reported in the literature would indicate. Single cases are still considered to be of enough importance and interest to warrant their report, and that is the reason for reporting this case.

REVIEW OF THE LITERATURE

Pneumocephalus was first described by Chiari, who noted the presence of air in the cranial cavity during autopsy in a case of purulent ethmoiditis with erosion of bone, in 1884. Luckett, in 1913, was the first to recognize intracranial air roentgenologically. It is only in recent years that its clinical significance has become appreciated. A review of the literature by Killian, in 1938, showed that only 110 cases had been reported up to that time, including 1 of his own. Of these 110 cases, 17 were caused by gunshot fractures, 7 were gas-containing abscesses, 59 were caused by fractures of the frontal bone, 16 were caused by fractures of the base of the skull and 11 were caused by tumors—osteomas in the region of the roof of the orbit and of the ethmoid, with perforation of the dura in the vicinity of the cribriform plate. On the other hand, Gurdjian and Webster, in 1944, reported having treated 31 patients with compound depressed fracture of the frontal sinus and its neighborhood, 9 with pneumocephalus, during the twelve year period 1930-1942.

Pneumocephalus may be classified, according to cause, as traumatic or nontraumatic (sometimes termed spontaneous). Four varieties occur, depending on the location in which the air collects. It may collect in, or it may be forced into, (1) the subdural space, (2) the brain substance, (3) the ventricles and (4) the subarachnoid space.

Read at the Fifty-Fifth Annual Meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 6, 1947.

Subdural Collections of Air.—Subdural collections of air are the commonest type, but have been reported only after fracture of the frontal sinus. In the frontal region the arachnoid is closely adherent to the brain, and the subdural space is potentially a space of considerable size, so that any tear in the dura here, communicating with the frontal sinus by a fistulous tract, may be accompanied with a subdural pneumatocele. Air traversing such a fistulous tract can fill only the subdural space if the brain and meninges remain intact. The subarachnoid space cannot be filled with air from this source, because here the spaces are too small and the arachnoid is so closely adherent to the brain. Roentgenograms of such subdural collections of air are diagnostic. They show an elliptic shadow following the line of the curvature of the skull.

Intracerebral Pneumatocele.—Intracerebral pneumatocele may result if the dura and arachnoid membrane are torn and the cerebral cortex is broken simultaneously with a sinus—frontal or ethmoid. However, adhesions must first form between the brain and dura, walling off a fistulous tract and preventing air from reaching the subdural space, through which the air will be able to follow a continuous tract from the fractured sinus into the frontal lobe during short periods of sudden and forceful increase of pressure, as on coughing or sneezing. Each such forceful discharge of air into the frontal lobe traumatizes and destroys the brain tissue. In addition, the air, imprisoned, as it were, because it has no easy exit, acts as a foreign body irritant and causes inflammatory edema and softening of the surrounding brain tissue. Thus, the adjacent brain tissue is more easily destroyed and the air cavity is more readily enlarged. The increase in size of the aerocele and the inflammatory reaction with its edema interfere with the circulation of the cerebrospinal fluid and cause increased intracranial pressure with all its symptoms and consequences, similar to that caused by a brain tumor. At the same time, usually several weeks after the air has entered the brain tissue, a wall of granulation tissue is being formed in the frontal lobe about the enclosed air. In some cases this wall is able to keep the process localized. In other cases, if the original tear is larger, or if the fistulous tract is valvelike, and if coughing or sneezing is frequent and severe, this wall is inadequate to keep the process localized, and it finally ruptures into the ventricle. When this occurs, the patient has sudden relief of symptoms. From the ventricles the air tends to pass through the foramens of Luschka and Magendie into the subarachnoid space. In some instances rupture into the ventricle may terminate the pneumocephalus, because the air is readily absorbed from the ventricles and the subarachnoid space.

Intraventricular Pneumocephalus.—Intraventricular pneumocephalus results either from the intracerebral variety, as just outlined, or from the subarachnoid variety.

Subarachnoid Collections of Air.—Subarachnoid collections of air occur practically only in the region of the cisterna magna. The reason for this is that elsewhere the arachnoid is so closely applied to the brain that entrance of air is impossible, whereas in the region of the cisterna magna the arachnoid is widely separated from the brain and closely adherent to the dura, so that it gets torn whenever the dura is torn. The only sources from which air can gain direct entrance into the subarachnoid space is from air cells in the sphenoid or posterior ethmoid sinuses, when these are fractured. Because fractures involving them are of infrequent occurrence, this variety of pneumocephalus is not nearly so common as that which follows fracture of the frontal sinus. This variety may follow erosion of the bone by tumor. Just as intraventricular air is likely to escape into the subarachnoid space, air in the subarachnoid space tends to ascend through the foramens of Magendie and Luschka and promptly reach the lateral ventricles.

Mixed Varieties.—Mixed varieties frequently occur.

Traumatic Pneumocephalus.—Traumatic pneumocephalus is much commoner than the nontraumatic type, and in the majority of cases it is due to fracturing of the intracranial surface of the frontal, ethmoid or sphenoid sinuses or of the mastoid cells. The first two sources are commoner. Killian, who reported pneumocephalus caused by fracture of the left frontal bone, with a large frontal lobe pneumatocele that healed spontaneously, found, in analyzing 110 cases of pneumocephalus reported in the literature to that time, including his own, that 17 followed gunshot fractures, 59 fractures of the frontal bone and 16 fracures of the base, making a total of 92 cases of the 110 due to fractures.

Nontraumatic Pneumocephalus.—Nontraumatic pneumocephalus (also known as spontaneous pneumocephalus) usually is caused by erosion through the intracranial surface of the paranasal sinuses or mastoid cells by a tumor or an infectious process. Historically, it is interesting to note that the first case of pneumocephalus described in the literature was of the nontraumatic type, due to purulent ethmoiditis, reported by Chiari,[1] in 1884. Killian, in his analysis of 100 cases of pneumocephalus reported up to 1938, found that the condition in only 18 was of the nontraumatic type; in 7 it was gas-containing abscesses, and in 11 the cause was tumor, osteoma in the region of either the orbit or the ethmoid, in the vicinity of the cribriform plate. Cushing, in 1927, reported a large intracerebral aerocele associated with an orbitoethmoid osteoma. Kessel, in 1939, collected 15 similar

cases from the literature and added 1 of his own. Hill, in 1942, reported a case of pneumocephalus secondary to a nasopharyngeal fibroma. Koch, in 1940, reported pneumocephalus secondary to chronic otitis media and cholesteatoma. Urfer, in 1943, reported a case with rupture into the ventricle following an otogenic temporal lobe abscess. Muir, in 1938, described an unusual case in which air collected under the pericranium and communicated with the interior of the skull.

SYMPTOMS, SIGNS, DIAGNOSIS AND COURSE

The possibility of pneumocephalus should be borne in mind whenever one is caring for a patient suffering from any of the aforementioned conditions, especially in cases of compound depressed fracture of the frontal sinus and its neighborhood. The two most characteristic symptoms are (1) cerebrospinal rhinorrhea, and (2) symptoms of increased intracranial pressure.

Pneumocephalus should be suspected when signs of increased intracranial pressure persist after the period of acute trauma has passed or if they first make their appearance after that time. Headache increased by sneezing is an important sign. In some cases the headache is excruciating. Dizziness, nausea, vomiting, bradycardia, gradual but progressive mental deterioration, cerebration becoming progressively slower, somnolence and even coma have been reported. Hemiparesis and hemiplegia have been seen. Convulsions may occur. The manner in which intracerebral aerocele produces symptoms resembling brain tumor has already been explained. If the onset of pneumocephalus is sudden, there is sudden severe headache and sudden collapse, suggestive of shock. Air in the subdural or subarachnoid spaces may cause localized pressure with focal symptoms. The intracranial pressure usually is not increased much. It may be steady or periodic. Part of the air may be absorbed, with improvement of mentality. Choked disk may occur, but it has been noted in only a few of the reported cases.

Cerebrospinal Rhinorrhea.—Cerebrospinal rhinorrhea is the most important single symptom. However, this characteristic symptom is not always present. In a few cases pneumocephalus may be present without cerebrospinal rhinorrhea. Van Zyl reported such a case in 1935. Killian, in 1938, pointed out that, whereas frontal lobe aerocele in general is a late complication, in the case of fractures of the base the pneumocephalus as a rule is demonstrable immediately after the accident. One recognizes, also, an immediate loss of cerebrospinal fluid, corrsponding to the collection of air, whereas in pneumocephalus that develops late the rhinorrhea tends to appear only after some weeks, as in the case herein reported. Pneumocephalus may not ap-

pear until after many weeks, or even months, following the injury to the skull. Such cases have recently been reported by Stuck and Weatherby (1940), Echols and Holcomb (1941) and Campbell, Howard and Weary (1942). Gurdjian and Webster, in 1944, referred to the aforementioned recent publications. They pointed out that complicating cerebrospinal rhinorrhea may be present in such cases and, further, that cerebrospinal rhinorrhea may be present without complicating pneumocephalus and called attention to the patient of Fribourg-Blanc, Lassale and Germain, in whom pneumocephalus did not appear for seventeen years, although the patient's history suggested occasional cerebrospinal rhinorrhea (two or three times yearly).

Symptoms Resulting from Infection.—Symptoms resulting from infection are always likely to develop. However, if the paranasal sinuses or mastoid cells are sterile at the time of the accident, and remain so, spontaneous cure may occur or the pneumocephalus may persist for weeks, or even for months, without any evidence of infection of the meninges or brain. In many reported cases it is clear that air was coughed or sneezed from the paranasal sinuses into the brain for such long periods, without infection resulting. On the other hand, if the paranasal sinuses or the mastoid cells are infected at the time pneumocephalus develops, it is almost inevitable that the intracranial contents will become infected and meningitis or brain abscess will follow. If infection occurs in the subdural variety, surgical drainage offers hope. If infection occurs in a cavity of the frontal lobes, the outlook is still serious, but more hopeful than in the preceding variety. If infection occurs in the intraventricular or in the subarachnoid varieties, the meningitis that follows is almost invariably fatal.

Diagnosis.—The diagnosis of pneumocephalus can usually be made from the history and the previously described clinical observations. Rhinorrhea, after such an accident, will indicate the probable presence of pneumocephalus or the likelihood of its future development. The production of rhinorrhea on tilting the head forward is an absolutely diagnostic sign that a large and direct fistulous tract exists into the cranial cavity. This sign is not so constant or so apparent if the fisula is small or has a valvelike opening. Roentgenologic examination of the skull is the one infallible method of diagnosis. The roentgenographic observations are typical and make the diagnosis absolute. Eaglesham (1945) contributed an important article, "Radiologic Aspects of Intracranial Pneumocephalus."

If there is any question as to whether or not cerebrospinal fluid is present in a nasal discharge—i.e., that it is cerebrospinal rhinorrhea—it can be answered definitely by means of the indigo-carmine test.

This consists of introducing 1 cc. of indigo carmine into the subarachnoid space of the spinal canal by means of routine spinal puncture. The indigo carmine promptly stains the cerebrospinal fluid bluish green, and this will be seen in the nasal discharge within about fifteen minutes and will continue for two or three hours. Thus used, indigo carmine has been of value in identifying the site of the opening of the cranionasal fistula within the nose. This has proved to be of practical use in attempts to close the fistula by applying a 20 per cent solution of silver nitrate, as was done with success by Fox in a case of spontaneous cerebrospinal rhinorrhea, after he identified the opening through the cribriform plate.

TREATMENT

Management in these cases may be operative or nonoperative (conservative). Dandy, in 1944, stated:

> Fistulas should be closed when possible and as soon as possible . . . Spontaneous cures do occur and not infrequently, but the risk of awaiting nature's decision is far too great to be justifiable . . . Dural openings over the posterior ethmoidal and sphenoidal sinuses are not accessible to direct attack.

Teachenor, Dandy, Cairns, Munro and Coleman advocated operative closure of the meninges if the rhinorrhea does not cease within four to six days after the time of injury. Rand, on the other hand, in 1945, stated:

> In approximately 40 per cent of the cases recovery is spontaneous if the patient is kept absolutely recumbent and quiet. He should be cautioned against coughing or sneezing or straining at stool. He should not feed himself . . . In some cases operation is necessary to free the brain of air and to close the rent in the dura. Gratifying results are usually obtained. Recovery has followed operation even in the presence of bacillary meningitis.

Gurdjian and Webster, basing their conclusions on a review of the literature and their experience in treating 31 patients with compound depressed skull fractures of the frontal sinus and its neighborhood, 13 with cerebrospinal rhinorrhea and 9 with pneumocephalus, stated:

> Pneumocephalus may be treated conservatively with success in some cases. Pneumocephalus due to cerebrospinal or bloody otorrhea may be treated by rest in bed with little fear of infection. Frequent roentgen investigations should reveal any increase in the intracranial air. If an increase is present, operative treatment may be advisable. Pneumocephalus associated with cerebrospinal rhinorrhea is dangerous, and the treatment of choice is operative repair of the cranionasal fistula. In pneumocephalus, irrespective of portal of entrance, operative repair is indicated when subsequent roentgen examinations show that the amount of intracranial air has increased.

Money and Stoller, in 1943, basing their conclusions on their experience in an unusual case and a critical review of the literature, stated:

> The recent advances in chemotherapy . . . have altered the plan of treatment for these cases by enabling infection to be controlled whilst spontanous cure of

rhinorrhea and absorption of air is awaited, also during and after operations . . . In the absence of signs of infection or increasing intracranial pressure no active treatment is necessary at first, but radiological examinations of the skull should be repeated at weekly intervals, in order to determine whether the pneumocephalus is being absorbed or not. Up to six or eight weeks may be allowed for the spontaneous absorption of the air and the closure of the fistulous tract . . . If, on the other hand, the pneumocephalus is not being absorbed, or is increasing, even before signs of increased intracranial tension and infection occur, operation is indicated to close the fistulous tract because it is considered certain that infection will follow sooner or later or that signs of increased intracranial pressure will eventuate. Should rhinorrhea persist or make a delayed appearance, the indication for operation becomes even more imperative.

Adson, in 1942, stated:

The incidence of rhinorrhea after fracture of the skull varies from 2 to 5 per cent. In view of the fact that rhinorrhea sometimes is spontaneously cured, I am inclined to wait six or eight weeks before advocating repair of the craniosinus fistula unless the fracture is compound and involves both walls of the frontal sinus.

In the patient herein reported, the rhinorrhea began, so far as can be ascertained, some time between May 12, 1947, and May 20. It ceased July 3 and had not reappeared as of the time of writing. Thus, it did not continue for more than seven weeks at most. The favorable outcome without operation in this case substantiates the position of Adson in cases of rhinorrhea and of Money and Stoller and of Rand in cases of pneumocephalus associated with rhinorrhea.

Operative Treatment.—Operative treatment carried out in cases reported in the literature has usually been undertaken for the cure of coexistent rhinorrhea and seldom for pneumocephalus alone. The fundamental principles of operative treatment were contributed by Dandy, in 1926, and Rand, in 1930. Dandy, Coleman and Cairns advocated early operation to close the torn dura by a direct approach through the frontal sinus for fracture in this region or an extradural approach through a unilateral frontal craniotomy for fistulas communicating with the ethmoidal or sphenoidal sinuses. If the dura about the hole can be mobilized, it may be possible to close it by sutures. Both an extradural and intradural approach may be desirable in cases in which the cranionasal fistula is in the posterior portion of the cribriform plate and over the sphenoidal sinus (Gurdjian and Webster). Usually, however, some additional means is required to close the fistula. Dandy, Rand, Cairns, Campbell, Howard and Weary, Gissane and Rank have used an autotransplant of fascia lata, sutured in place to close the defect in the dura. Other surgeons have used temporal fascia, pericranial fascia (Trotter, cited by Lawson), osteoperiosteal transplant from the tibia (Gissane and Rank), cauterization of the fistula and plugging it with a transplant of muscle (Echols and Holcombe), a piece of fascia lata placed over the defect intradurally, without suture (Stuck and Weatherby), and an oval flap of falx

cerebri (Gurdjian and Webster). Adson has observed that a bifrontal craniotomy gives a much better exposure than a unifrontal flap. He used a coronal scalp incision within the hair line. Care is taken to avoid the longitudinal sinus, but if bleeding occurs from it, the sinus is ligated with silk 6 cm. above the foramen cecum and the dura is elevated from the frontal fossa, from both sides of the cribriform plate at once, and the olfactory grooves. The fistulous tract is then separated and invaginated with fine silk sutures, and the suture line is reenforced with a piece of muscle, which is transfixed to the dura and further reenforced by placing a second row of interrupted silk sutures. The defect in the frontal sinus or cribriform plate is filled with Horsley's bone wax. Further, to protect against forcing of the wax through the cranial defect into the sinus or nose, Luken's animal membrane is placed over the defect before the introduction of the wax to plug the hole. Adson stated that the advantages of bifrontal craniotomy are as follows: 1. A better exposure is obtained than by employment of a unifrontal flap. 2. The surgeon is always sure to identify the fistulous tract. 3. The exposure thus obtained affords a better opportunity for elevation of the meninges along the cribriform plate. 4 After elevation of the dura from the cribriform plate, tension on the dura is relieved; this permits greater ease of invagination of the fistulous tract and successful performance of overlapping dural closure of meningeal defects. Eden, in 1942, described the operative procedure used by Taylor in 2 cases of rhinorrhea, in 1 of which there was an aerocele in the left frontal lobe. Using the classic transfrontal intradural approach for a pituitary tumor, the frontal lobe was elevated from the dura at the site of the fistula into the frontal sinus. The defect in the dura was closed by means of a piece of fascia lata, held intradurally by pressure. No attention was given to closing the defect in the bone. In 1 of the cases, bilateral ethmoidal fistulas were present, the longitudinal sinus was ligated and, after incision of the dura across the midline, both frontal lobes were retracted; this gave complete exposure of the torn dura, which was closed by means of a large Y-shaped piece of fascia lata. Money and Stoller, in 1943, pointed out that in dealing with an aerocele of the frontal lobe, additional room and greater ease in retracting the frontal lobe, either extradurally or intradurally, can be obtained by needling the pneumocephalus with a blunt cannula and evacuating the contained air (Eden, in 1942, and we, in 1943) or air mixed with purulent fluid (Baker and MacLean, in 1941). They stated that in their case the affected frontal lobe collapsed like a punctured balloon. Peet (1928) inserted a wick of iodoform gauze at the site of the tear of the membranes, leaving it in place for four or five days, to make the brain become adherent there and to shut off the spaces between the meninges.

REPORT OF A CASE

The patient, a man 23 years of age, was an automobile mechanic. About 4:30 p.m., March 31, 1947, while he was removing the tire from a truck wheel, the steel rim flew up and struck him in the forehead. He was knocked unconscious and was promptly brought to the hospital, by ambulance, where I first saw him, at about 4:45 p.m. He was then conscious, but dazed and in cerebral shock. The pulse rate was 56, and blood pressure was 178 systolic and 85 diastolic. There was a deep cut across his forehead, from just above the right extremity of the right eyebrow and curving slightly upward across the forehead to a point about 1 inch (about 2.5 cm.) above the left extremity of his left eyebrow. Frontal brain tissue was visible in the wound. He was cared for at once in the ambulance entrance operating room. There was ecchymosis of both right and left eyelids, especially the upper lids. There was no injury to either eye.

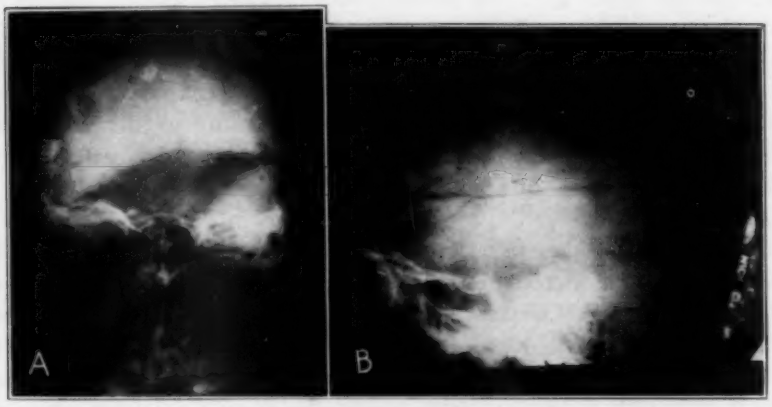

Fig. 1.—*A*, anteroposterior roentgenogram of the skull, April 1, 1947, showing the enormous defect of the frontal bones. Eight fragments were driven into the frontal lobes of the brain. One fragment was picked up from the floor of the garage at the site of the accident. *B*, lateral roengenogram taken April 1 (left side of the skull), showing the long fracture extending backward from the frontal bone defect through the parietal bone and occipital bone, to within 1 inch (about 2.5 cm.) of the back of the skull, with another fracture extending downward and forward from this long one and ending in the great wing of the sphenoid bone.

After surgical cleansing of the skin of the forehead and injection of 1 per cent procaine hydrochloride solution about the edges of the cut, the wound was cleansed by irrigation with a copious amount of sterile isotonic sodium chloride solution, with a large glass syringe. The soft parts were debrided, the cutaneous edges and underlying tissues of the edges of the large wound being cut away. Many loose bone fragments were removed from both right and left frontal lobes of the brain, after being located with the little finger of the left hand and grasped with a small artery forceps. Eight fragments in all were removed. These were full thickness fragments of the frontal bones. Another fragment was found at the scene of the accident. The resultant defect in the frontal bones was a band averaging about 2.5 cm. in width, extending from above the outer edge of the right eye to above the outer edge of the left eye. The sharp corners of the remaining fracture edges of both frontal bones were cut away with a rongeur to smooth the margins of the large bone defect about the exposed brain. After all bleeding blood vessels

were clamped and ligated, the wound edges were closed with many interrupted dermal stitches, without drainage. The large defect in the frontal bones left the brain here covered only with skin and underlying aponeurotic tissue. The operation was completed at 6:45 p.m., at which time the patient's condition was fair and the pulse rate was 56. Before the patient was removed from the operating table, dehydration treatment was begun, with 50 cc. of 50 per cent sucrose solution given intravenously.

Postoperative treatment consisted of (*a*) dehydration treatment: limitation of fluids by mouth, administration of 50 per cent sucrose solution intravenously and administration of magnesium sulfate by mouth and by enema, (*b*) administration of penicillin and (*c*) administration of tetanus antitoxin and gas gangrene antitoxin.

At 7:30 p.m. his blood pressure was 160 systolic and 60 diastolic, but his pulse rate was still 56. There was slight bleeding from his nose. At 10:30 p.m. epistaxis stopped. At 4:30 a.m., April 1, his blood pressure was 150 systolic and 60 diastolic, the pulse rate was 60 and the patient responded to conversation. During the night he vomited dark blood on two occasions. That day his temperature ranged from 99 to 100 F. (rectal), with blood pressure 130 systolic and 60 diastolic. Roentgenograms taken of his skull that afternoon showed the enormous defect of the frontal bones and a long fracture of the left side of the skull, extending backward from

Fig. 2.—Photograph of the fragments of frontal bones removed at operation—eight fragments were within the frontal lobes of the brain. One large fragment included in the group was picked up from the garage floor at the site of the accident.

the frontal bone defect, through the parietal bone and to within 1 inch (about 2.5 cm.) of the posterior wall of his skull, with another fracture extending downward from his long fracture and forward into the great wing of the sphenoid bone (fig. 1).

From the morning following the operation the patient was clear mentally. That morning he did not have much headache, and by April 4 he had no headache. However, dehydration treatment was continued until April 7, because his blood pressure varied from 160 systolic and 60 diastolic to 140 systolic and 60 diastolic during these six days. He was unable to open his eyes during this time because of edema and ecchymosis of the lids, as shown in a photograph taken on April 6 (fig. 3.). At the time this phoptograh was taken there was some seepage of bloody serum from the wound, at a point somewhat to the left of its center, over his left eye. Next morning, April 7, his blood pressure was down to 134 systolic and 55 diastolic. Consequently, dehydration therapy was discontinued. Administration of penicillin, 30,000 units every three hours, i.e., 240,000 units daily, was continued for twelve days, that is, until 9 a.m., April 12—a total of 2,880,000 units.

There was progressively less serosanguineous discharge from the left side of the wound, which otherwise was completely healed by April 14, when all cutaneous stitches were removed. On April 17 he was allowed to be out of bed. Some seepage

continued from the small opening in the wound, over his left eye, first serosanguineous and later seropurulent (liquefied necrotic brain tissue), accompanied with a slight elevation of temperature at times, never more than half a degree, until May 3, when the wound was dry and remained so. His temperature had been normal or essentially normal since April 9.

Fig. 3.—Photograph of the patient, April 6, 1947; his eyes are still swollen shut by edema and ecchymosis of the lids. The long wound can be seen, with stitches still in place. There is slight seepage of bloody serum from a small opening in the wound, over the left eye.

Fig. 4.—Anteroposterior roentgenogram of the skull, taken on May 12, 1947, at the end of six weeks from the date of the accident and operation, the day he was discharged from the hospital to home. This looks much the same as the first one taken, the day following the operation.

The patient was discharged on May 12. He looked and felt well, free from any headache or dizziness. A roentgenogram of his head was taken that day. It looked much the same as the first one taken (fig. 4). A photograph taken that day shows the extent of the wound across his forehead (fig. 5).

On his return visit for a check-up, May 20, he reported that clear fluid had been dripping from his nose for the past several days. He expressed the belief that he had a "cold." I realized that it was cerebrospinal rhinorrhea—a leak through a fracture, probably of the cribriform plate of the right side of the ethmoid bone.

I gave him a small glass vial and instructed him to collect some of this fluid, so that it could be examined. I wished to have it examined chemically and microscopically, to prove that it was cerebrospinal fluid. He returned on May 26 with

Fig. 5.—Photograph of the patient, May 12, 1947, the day he was discharged from the hospital, at the end of six weeks from the day of the operation.

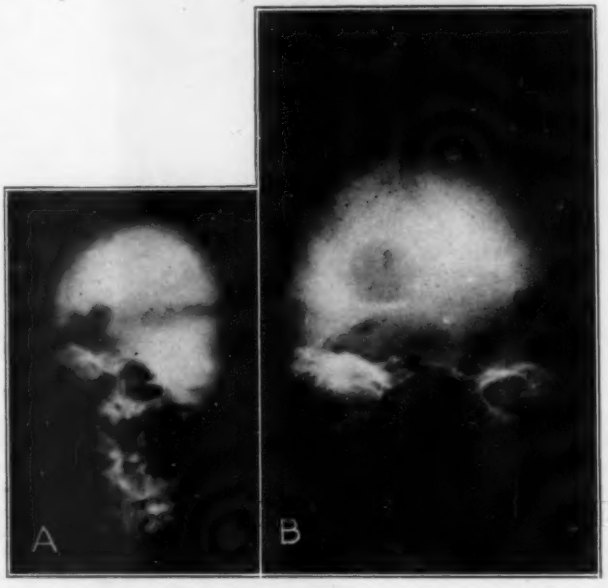

Fig. 6.—*A*, roentgenogram of the skull, May 26, 1947, showing intracranial collection of air on the right side, above the right orbit, i.e., intracranial pneumocephalus. *B*, roentgenogram of skull, June 10, showing the clearcut pneumatocele on the right side, above the level of the defect in the frontal bone.

a small sample of the fluid. It looked like cerebrospinal fluid, but the amount was too small to prove that it was. He said that he had been unable to collect more because there was much less discharge from his nose. A roentgenogram was

taken of his skull, to determine whether intracranial pneumocephalus was present. The roentgenogram (fig. 6*A*) plainly showed an intracranial collection of air on the right side, above the right orbit. He was instructed to be quiet and to lie in bed most of the time. He was told that if the discharge did not entirely cease he would be rehospitalized, to remain flat on his back for two weeks or more, until all

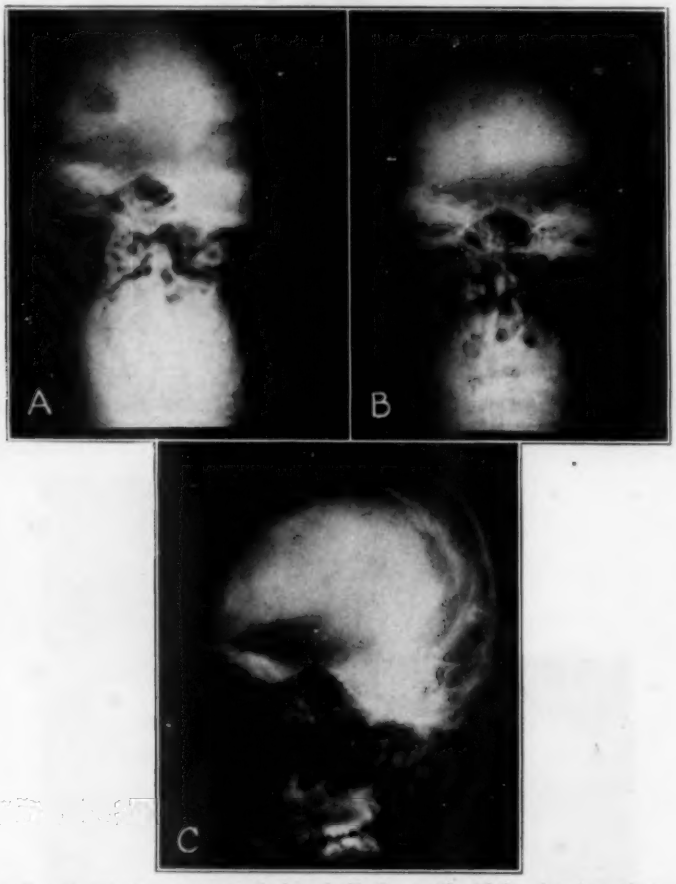

Fig. 7.—*A*, roentgenogram of the skull, June 17, 1947, showing that some air is still present but that the pneumatocele is definitely smaller. This shows that some of the air had been absorbed since June 10. *B*, roentgenogram of the skull, July 10, showing that there is no air within the skull. A recheck roentgenogram, October 17, likewise showed no air within the skull. *C*, roentgenogram of the skull, November 25, showing that there is no air in the skull and that there is some filling in of the huge bone defect by osteoid tissue. This explains the fact that palpation at that time over the bone defect showed that his forehead was firm.

discharge had ceased, and that during his time he would not be allowed to feed himself, but would be fed by a nurse.

He was next seen on June 10. He stated that the amount of discharge had been lessening progressively. He was free from headache and dizziness. A roentgenogram was taken (fig. 6*B*), and this showed a clearcut pneumatocele, i.e., that air was still present.

The cerebrospinal rhinorrhea completely ceased on June 13. A roentgenogram taken on June 17 (fig. 7*A*) showed that some air was still present but that the pneumatocele was definitely smaller, i.e., that the air was being absorbed. Rhinorrhea recurred for one day only, on July 3, and did not return. A roentgenogram taken on July 10 (fig. 7*B*) showed no air within the skull. A roentgenogram taken October 17 likewise showed no air within the skull. He returned to work at his old job on August 16, 1947, where he is still working full time, without any headaches or dizziness.

When last seen, on November 25, another roentgenogram was taken (fig. 7*C*), and this, too, showed no air within the skull, but it showed some filling in of the huge bone defect by osteoid tissue. A photograph was taken of him the same

Fig. 8.—Photograph (not retouched) taken on Nov. 25, 1947. Palpation over the bone defect showed that the forehead was firm. The patient returned to his job; he was symptom free, with no headache and no dizziness.

day (fig. 8). This shows his appearance as of the time of writing. Palpation over the bone defect showed that his forehead was firm.

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DISCUSSION

DR. WILLARD BARTLETT, JR., St. Louis: I should like to ask Dr. Schmidt whether any of his patients have had intense flushing of the face and neck and any other signs suggestive of dermatomyositis without having actual dermatomyositis.

DR. ERWIN R. SCHMIDT, Madison, Wis.: In the case in which there was a bilateral condition, yes; in the other cases, no. I do not know the reason. The patient with the bilateral condition was a man of rather full and red face and heavy weight. One usually sees such persons with a red face or redness of the upper part of the neck, who flush easily.

I doubt whether there was any particular relation, because the other 3 patients were rather thin women, and they did not show any signs of flushing.

ATYPICAL NEURALGIA OF THE FACE

ERWIN R. SCHMIDT, M.D.
AND
HENRY A. SZUJEWSKI, M.D.*
MADISON, WIS.

SHERRINGTON[1] defined pain as the psychic adjunct of an imperative protective reflex. The pathways for pain have usually been explained on a somatic basis. Other means for the explanation of pain had to be found when there was no explanation on a somatic basis. Some of these clinical examples are seen in coronary cardiac disease, pulmonary thrombosis, pericarditis, distention of the gallbladder, intestinal obstruction, Dietl's crisis, migraine, thrombophlebitis, thromboangiitis obliterans (Buerger's disease) and others.

There are many types of neuralgia of the face, and the title of our paper is a misnomer. It should be "Vascular Pain of the Face." However, we have chosen the commonly used term as the condition is so designated clinically and described under this title in the literature.

Leriche[2] listed the following types of neuralgia of the face that are not of trigeminal nerve origin:

1. Transient, due to some curable condition
2. Neuralgia of sphenopalatine ganglion (Sluder's neuralgia)
3. Neuralgia of soft palate and pharynx
4. Neuralgia of glossopharyngeal nerve
5. Neuralgia of geniculate ganglion
6. Frontal neuralgia
7. Deep-seated pain in face following sinus operations
8. Neuralgia symptomatic of an intracranial tumor
9. Tumors of the gasserian ganglion
10. Myositis of the masseter and temporal muscles
11. Sympathalgia
12. Facial psychalgia

There are others, and the differential diagnosis for the treatment is most important.

Attention to this type of vascular pain was called by Fay[3] in 1927 as atypical neuralgia. Pressure caused the carotidynia. Whereas a normal carotid sinus produced reflex dilatation of the pupil on the

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From the Department of Surgery, University of Wisconsin Medical School.

Read at the Fifty-Fifth Annual Meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 6, 1947.

1. Sherrington, cited by Livingston, W. K.: Pain Mechanisms, New York, The Macmillan Company, 1943.

2. Leriche, cited by Young, A.: The Surgery of Pain, Baltimore, Williams & Wilkins Company, 1939.

3. Fay, T.: Atypical Neuralgia, Arch. Neurol. & Psychiat. **18**:309 (Aug.) 1927.

same side, well developed atypical neuralgia caused the pupil to dilate more fully and to remain dilated longer. In 1942 Fay[4] presented another paper, in which he gave the symptoms and observations at operations which were done under local anesthesia. A common symptom was dull aching throbbing pain, situated deep in the eye and malar region, directed toward the ear. It may be referred to the back of the neck, behind the ear and in the lateral aspects of the neck. Occasionally it will radiate to the shoulder and axilla. This follows no neurologic pattern. At operation, done under local anesthesia, different areas on the carotid sinus were stimulated with faradic current, and pattern representation of the vascular supply of the face was ob-

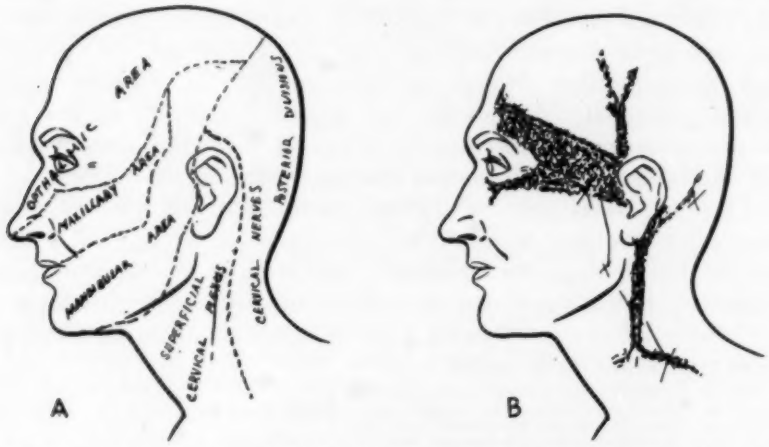

Fig. 1.—*A*, innervation of the head and the neck. *B*, distribution of vascular pain in the head and the neck.

served. We have observed that, in addition to the history, the most helpful information came from careful stimulation of the carotid sinus on the affected side. This usually produces an attack of pain similar to that which the patient had. Care must be exercised in applying pressure to the carotid sinus. It is easy to produce dizziness and even unconsciousness.

Since Fay's paper in 1942 we have seen several cases. The fact that these cases are being overlooked was proved to us in our own institution. A report of a case at a staff conference brought a request for several consultations, and in our fourth case the disease was diagnosed and the patient operated on.

It is well recognized that the sympathetic system serves to mediate or play a role in producing pain. The example which comes to mind

4. Fay, T.: Atypical Facial Neuralgia: A Syndrome of Vascular Pain, Ann. Otol., Rhin. & Laryng. **41**:1030, 1933.

is the dramatic relief in thrombophlebitis following block of the lumbar ganglions with local anesthesia. White used local block in the pain of coronary disease. Fay, by using faradic stimulation on the carotid sinus and its branches, proved that pain could be caused in this way and that the pain could be relieved by operating on the patients and interrupting the sympathetic pathways.

Some of the causes of this sensitivity of the carotid sinus and the vascular pain as given by Fay are: (*a*) infection and inflammation and (*b*) reflex. (Some of these reflexes originated in the gallbladder and the apexes of the lungs. In the latter it was observed that some of these patients had had extensive nasal and oral operations. It was recommended that a detailed examination of the teeth, mastoid, sinuses, chest, abdomen and pelvis be carried out).

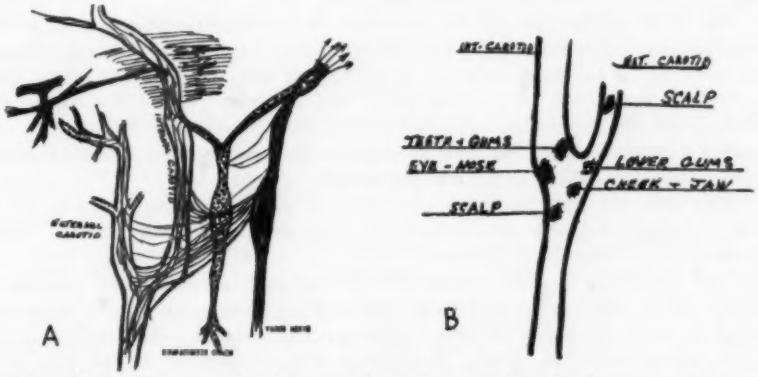

Fig. 2.—*A*, diagram showing the intimate relationship between the carotid vessels, vagus nerve and sympathetic chain. *B*, diagram showing the points of stimulation with faradic current to elicit referred vascular pain.

Our experience shows that a local inflammation, involving the tissue and lymph nodes, was the usual cause. We did not observe the reason for this inflammation in the areas drained by the lymphatic vessels or the cervical glands. We have not had any case so far in which we thought the condition to have reflex origin.

During the past year we have had 3 cases.

REPORT OF CASES

CASE 1.—A. W., a white man 36 years of age, complained of chronic dull aching headache, with pain over the eyes, behind the eyes and down the neck. This pain had been constant, varying in intensity, for almost six years. The patient noticed no trigger areas. He did notice that pressure over the side of the neck produced attacks of sharp facial pain and frontal headaches.

Physical examination revealed a rather obese man. His face was flushed, and he did not appear ill. Examination of the head showed definite tenderness over the occipital major, the external temporal and both supraorbital and infraorbital

nerves. The ears were normal. The eyes reacted to light and accommodation. The eyegrounds showed some narrowing of the arteries, and pressure on the carotid sinus bulb seemed to increase this narrowing. The nose was normal. The teeth were false; the tongue was clean, and the tonsils had been removed. In the neck there was definite tenderness on pressure over both carotid sinuses, causing the kind of headache of which the patient complained. The chest was normal except that the blood pressure was 145 systolic and 100 diastolic. The remainder of the examination revealed no further abnormalities, nor did the laboratory procedures, including roentgenograms of the skull and sinuses.

The patient was followed for several weeks. Tenderness to pressure over the carotid sinus bilaterally produced pain and set off an attack of severe bilateral headache. Delayed anisocoria was present. We made a diagnosis of bilateral atypical facial neuralgia. Operation on Nov. 12, 1946, with denudation of the right common carotid artery and its branches, was carried out. The arteries were stripped clean of all adventitia, with nerve fibers and all connections to the vagus interrupted. The immediate postoperative condition was good. Several days later there was no relief from pain on the right side.

One month later the patient returned for a similar operation on the left side. Since his last admission he had had considerable relief from pain on the right side, although some pain persisted. On the left side there was pain as before. On December 17, the left carotid bulb and branches were denuded of their sheaths, with the nerve fibers and the vagus communications interrupted. A large hematoma occurred after the patient was returned to his room, and this had to be evacuated. His convalescence was uneventful.

After discharge this patient was followed up in the outpatient clinic. He was much improved and able to carry on his work. The relief was gradual. During observation hypertension developed.

Case 2.—M. C., a white woman 40 years of age, complained of pain in the left side of her face. This had been present for fifteen years, and it began with a swelling of the glands in the left side of her neck. It was a dull throbbing pain and tended to follow the course of the large blood vessels on the left side of the face and extend down her shoulder. Changes of weather seemed to precipitate attacks, and pressure over her carotid sinus would cause the pain. Heat or light made the pain worse, and cold seemed to relieve the pain.

Her past medical history revealed that she had had an appendectomy twelve and one-half years prior to examination, a thyroidectomy thirteen years, and a tonsillectomy eleven years prior to examination. A hernia on the right side had been repaired. She had had sinus trouble for years.

The pertinent physical observations were: tenderness over the occipital major, superficial temporal, supraorbital and infraorbital nerves on the left side. Tenderness was present over the temporal artery and over the facial artery where it crossed the mandible. Pressure over the left carotid sinus tended to cause the pain over the left side of her head and face. The teeth were in good repair. The tonsils were absent. Deep pressure close to the cervical vertebrae on the left produced a pain in the upper aspect of the left scapula, and pain radiated down her left arm. The blood pressure was 150 systolic and 90 diastolic. Roentgenograms of the teeth, mandible and sinus revealed no abnormalities.

On March 16, 1947, the left carotid sinus and carotid arteries were denuded of adventitia and nerve fibers with their connections to the sympathetic ganglions and the ninth and tenth nerves. The patient had some pain on discharge from the hospital. Several weeks later the relief of pain was complete.

Case 3.—The patient was a young woman with a history similar to that in case 2. She was treated the same way, with complete relief.

The record of a fourth patient treated four or five years prior to the date of writing, has been lost, but the condition was similar to that in the other 3 cases.

COMMENT

The normal and pathologic functioning of the carotid sinus is well described by Weiss and Baker,[5] Tchibukmacher[6] and Fay.[4] While the function of the carotid sinus is related to blood pressure and pulse rate, the signs and symptoms of the sensitive carotid are many. Weiss and Baker enumerate them as (1) subjective symptoms, such as dizziness, blurring of vision and ringing in the ears, and objective signs, such as pallor, fainting and convulsions, (2) gross changes in the structure of the sinus, (3) effect of bodily posture on the symptoms, (4) slowing of the heart rate, (5) fall in arterial blood pressure, (6) electrocardiographic changes, (7) diminution in cardiac output and increase in circulation time and (8) changes in the gaseous content of the blood obtained from the internal jugular vein.

The distribution of the neuralgia along the course of the larger blood vessels as described by Fay and the relief by means of stripping the carotid sheath off the carotid sinus and its branches are verified in our 4 cases.

Our experience indicates that the condition is easily and often overlooked. The history is rather typical. The condition may involve several of the larger vessels or only some of them. The pain is a dull throbbing behind the eye, over the malar eminence and radiating to the ear, suboccipitally, or down the neck and arm. It varies, but is fairly persistent. The history usually reveals the pain to have been of long duration, with many types of medication and treatment by many physicians. Carefully applied pressure over the carotid sinus will reproduce the pain. In our cases, the local pathologic change seen at the time of operation was of a chronic inflammatory nature, involving the local tissue and lymph nodes. The diagnosis is fairly simple, and yet in our institution a review of cases seems to reveal enough data to raise the question as to whether they may not be cases of vascular pain amenable to treatment.

Segerberg and Mayfield[7] reported the cure of a sensitive carotid sinus by section of the nerve of Hering. They made the point that,

5. Weiss, S., and Baker, J. P.: The Carotid Sinus Reflex in Health and Disease: Its Role in the Causation of Fainting and Convulsions, Medicine **12**:297, 1933.

6. Tchibukmacher, N. B.: Surgical Anatomy of Carotid Sinus Nerve and Intercarotid Ganglion, Surg., Gynec. & Obst. **67**:740, 1938.

7. Segerberg, L. H., and Mayfield, F. H.: The Carotid Sinus Syndrome: A Case Report with Cure by Resection of the Nerve of Hering, Christ Hosp. M. Bull. **1**:27, 1947.

in stripping the adventitia from the sinus and the branches, there was considerable risk, because of the occurrence of atheromatous plaques and perforation of the vessels. We have observed no arteriosclerosis in our patients, but in 2 of the 4 patients operated on there was a great

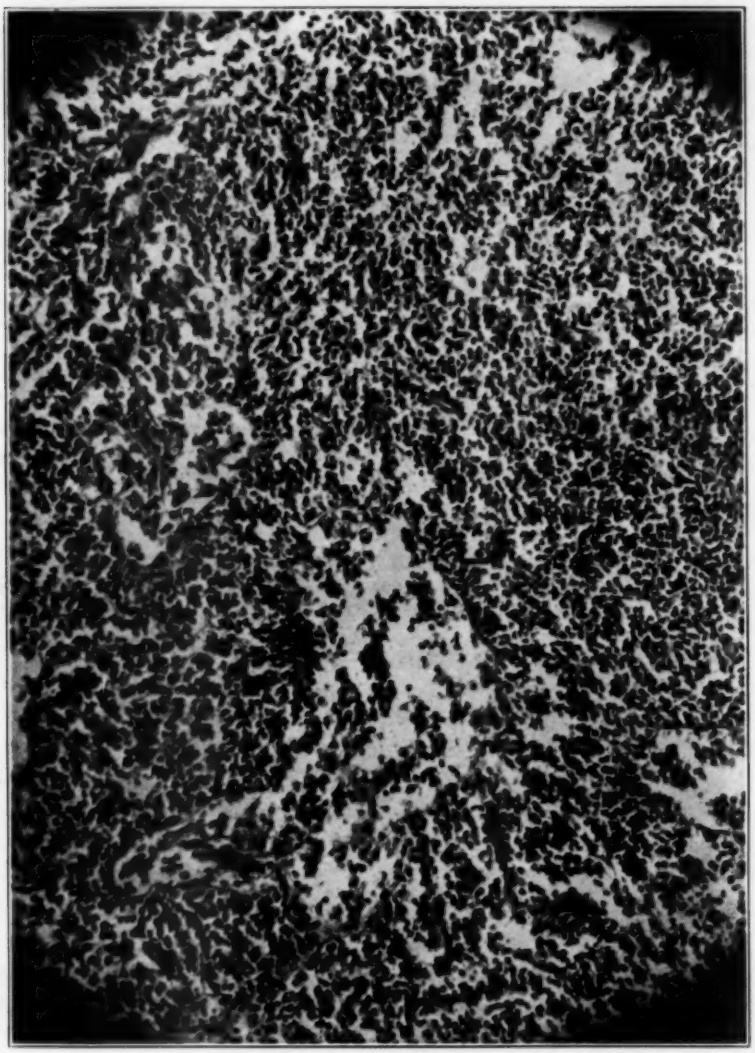

Fig. 3.—Section of lymph node.

deal of capillary ooze from the denuded vessels. We always put in a drain through a stab wound. In 1 case the bleeding was severe enough to cause pressure difficulty in breathing. Fay[4] mentioned the procedure which he felt was necessary. The carotid bulb must be com-

pletely denuded and should include the bifurcation and the two large branches arising from it. The freeing of the posterior wall is more difficult, because the vessels must be rotated. Even when the procedure has been carefully done, the results have been variable and incomplete.

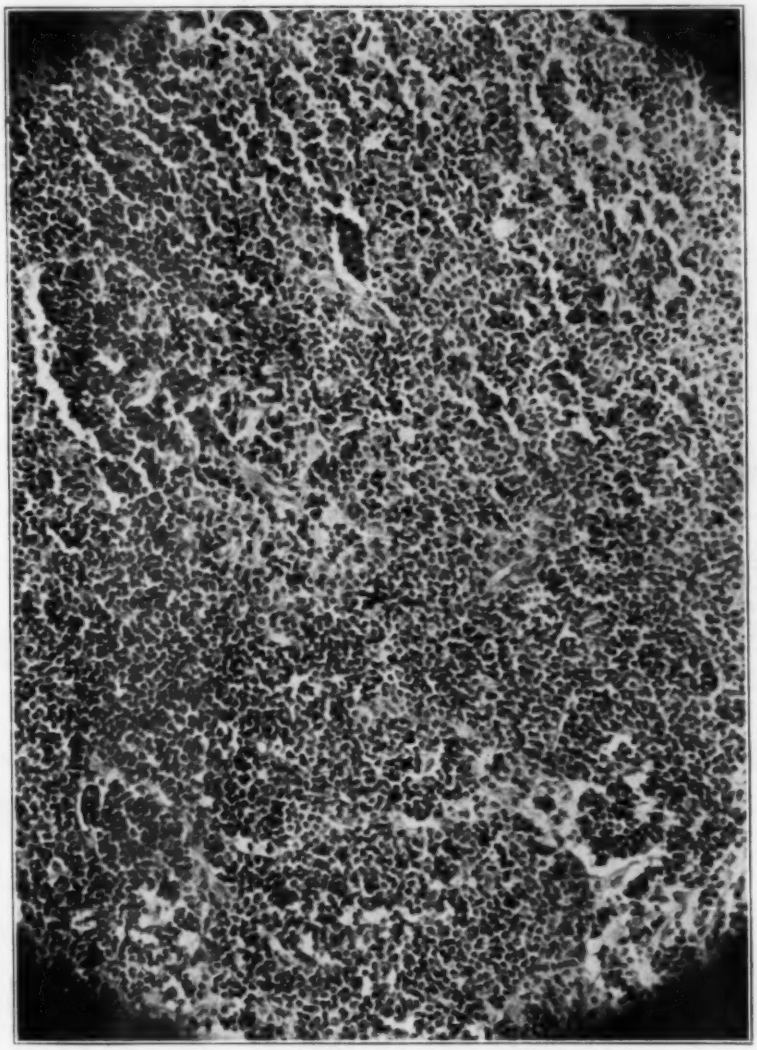

Fig. 4.—Section of lymph node.

One of our patients was observed to have what seemed like a recurrence or an incomplete result, but it was discovered that she had malocclusion of the molars, raising a question in our minds as to the diagnosis. It is a new tield, and the reports will not be accurate until

Summary of Data in a Series of Cases of Atypical Neuralgia

Patient	Age	Diagnosis	Typical Symptoms	Syndrome Recognized	Carotid Sensitivity	Evidence of Infection	Treatment	Secondary	Relief	Probably Atypical Facial Neuralgia
C. M.	29	Atypical facial neuralgia	+	+	Not tested	Pyorrhea; ulceration of left side of upper gum	Right and left lower incisors extracted		+	+
S. K.	43	Atypical neuralgia of head	+	+	Not tested	Sinusitis	None		—	+
A. N.	32	Atypical neuralgia of head, obscure	+		Not tested	None	None	Costen syndrome	—	+
G. B.	29	Neuralgia of occipital nerve	—		Not tested	None	None		—	+
E. G.	39	Occipital neuralgia	+		++	None	Procaine hydrochloride into occipital nerve		—	—
E. P.	64	Atypical facial neuralgia	+		Not tested	Influenza	None	Costen syndrome	—	+
M. N.	53	Mild neuralgia	+		Not tested	None	None	Costen syndrome	—	+
R. Mc.	57	Atypical fifth nerve neuralgia	+	+	Not tested	None	Alcohol injection into second division of fifth nerve		—	+
N. G.	30	Atypical facial neuralgia	+	+	++	None	Carotid denudation	Pain at insertion of maxilla	Decided	
M. C.	40	Atypical facial neuralgia	+	+	++	None	Carotid denudation	None	Decided	
A. W.	36	Atypical facial neuralgia	+	+	+++	Prominent lymphadenopathy	Carotid denudation	Hypertension	Almost complete	

the diagnosis is accurate. In a patient with a malignant condition of the parotid gland, removal by chemosurgery was contemplated. Because the deeper vessels were involved, ligation of the external carotid artery, between the lingual and the superior thyroid artery, was necessary. The patient had a great deal of pain previous to operation. After ligation metastases were seen in the lung, and no further treatment was carried out. Much to our surprise, the patient had remained free from pain as of the time of writing. The patient was operated on July 30, 1947, and was seen in the outpatient department just a few days prior to writing. The explanation is not clear.

One patient underwent bilateral denervation. Most of the reports indicate that following the stripping on one side there is a rise in the blood pressure, which soon returns to normal, and the usual reflex on stimulation is absent. Leriche, Fontaine, and Froehlich[8] did seven denervations of the carotid sinus, five of which were bilateral. The tension rose after operation and subsided in a few days. Patient A. W. (case 1) had a blood pressure of 145 systolic and 100 diastolic before any operation. The last time the patient was seen his blood pressure was 190 systolic and 120 diastolic. Whether the hypertension was under way before the operation or was aggravated by the operation we cannot say.

SUMMARY AND CONCLUSIONS

The observations of Fay were substantiated in our 4 cases; the neuralgia of the face of vascular origin was relieved in 3 cases and to a decided degree in the fourth case. These cases are frequently overlooked. A carefully made differential diagnosis of neuralgia of the head and neck will suggest the vascular origin of the pain.

8. Leriche, R.; Fontaine, R., and Froehlich, F.: L'énervation sinu-carotidienne est-elle permise au point de vue physiologique? Presse méd. **43**:1217, 1935.

SURGICAL USES OF POLYTHENE

An Experimental Study

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THIS study was undertaken because, in the course of another series of investigations, we became aware of the possibilities that one of the more recently developed plastics, polythene (polyethylene), might have in clinical surgery. Since we had been impressed with the physical characteristics of polythene and with its evident tolerance by one of the most sensitive of tissues, the intima of lymphatic vessels and veins, it was not long before we wished to determine what uses it might have to supplant, in part, living tissues and structures. We were aware of the history of the uses of foreign materials in living tissues. On the one hand, ligatures and sutures of certain materials have been proved by centuries of use to be tolerated by living tissues; in fact, before the introduction of the ligature, surgery consisted only in the treatment of suppuration. On the other hand, almost every proposed use of a foreign material to replace or fill a defect in tissue has been relegated to the wastebasket of surgery.

Our study was planned to find out whether a recently developed plastic, polythene, could be used to bridge a gap in living tissues in a few selected organs. We have had no reason during the study to change our original hypothesis that a foreign material is useful only as a means of establishing structural continuity of tissues which have simple mechanical functions rather than complicated biologic functions. For example, we preferred to investigate whether tubes of polythene could be used to establish continuity of the common bile duct, a duct with little function other than to conduct bile from the liver to the enteric tract. We have not been encouraged to determine whether polythene tubes would have more than a temporary use in establishing continuity of peripheral blood vessels, because tubes are incapable of vascular behavior.

From the Division of Experimental Medicine, Mayo Foundation.
Read at the Fifty-Fifth Annual Meeting of the Western Surgical Association, Colorado Springs, Colo., Dec. 6, 1947.

In the years since the beginning of surgery, science has advanced on a broad front. One is no longer restricted to a choice of silk, cotton, rubber and materials of this nature for use in surgery. From the biologic sciences, articles made of fibrin are offered as the best available absorbable foreign substance. From metallurgic experiments there are two acceptable metallic nonabsorbable foreign substances, vitallium and tantalum. In general, their advantages and disadvantages lie in the same qualities, rigidity and hardness, advantages when these substances are a substitute for various parts of the skeleton and disadvantages when they must substitute for a soft part. Chemistry has given us the only cheap and easily fabricated materials which promise to be of surgical use, the plastics. Acrylic plastic, or lucite, has proved to be acceptable as a foreign material and is extremely well tolerated by living tissues. Its well known disadvantages are its rigidity and, when it is thin walled, its brittleness.

Almost two years ago we began work on several problems which entailed making lymph fistulas that would flow continuously. We had no success until we began to use flexible, smooth-walled nonwettable plastic tubes as cannulas. The plastic tubes were so much better than any other tubes for this purpose that we were encouraged to begin some experimental studies to determine what plastics were best and what uses such plastics might have in clinical surgery. More specifically, we wished to know which could be permanently implanted in the body for the surgical reconstruction of various nonbony structures and organs. The ideal plastic should neither undergo changes when surrounded by living tissue and body fluids nor produce local or systemic biologic reaction. Tantalum, vitallium and lucite are satisfactory in their fulfillment of these criteria, but have had limited usefulness because of rigidity, hardness or brittleness. Therefore, we restricted our search to the more recently developed, flexible and not too hard plastics.

The first plastics with which we worked were the polyvinyl resin plastics, manufactured under various trade names. We have observed these plastics to be useful in many ways, but all suffer more or less from a common disadvantage—they become rigid soon after they have been buried in living tissue. This occurs because the plasticizers which they contain to give them flexibility are dissolved out by the ketones and esters of tissue fluids.

The plastic which we have observed to be by far the best of those now commercially available is polythene. Polythene is made by polymerizing ethylene by heat and pressure. This results in molecules of long carbon chains, the loose bonds being occupied by hydrogen atoms. Ordinary paraffin is likewise polymerized ethylene, but the carbon chains are much shorter than in the polythene molecule. In

many respects polythene resembles paraffin. It has the same cloudy color and, in thin sheets, transparency. It is not wetted by water; it can be molded when it is heated to its softening point; it is light in weight, a poor conductor of heat, an excellent electric insulator and is nonradiopaque. In such respects it has all the advantages of paraffin, including, because of its nonwettability, the advantage that blood clotting is greatly delayed in polythene tubes. Unlike paraffin, polythene is rather flexible, has great tensile strength, has a softening point above the temperature at which water boils (and consequently may be sterilized by boiling water) and is insoluble in, and unaffected by, all acids, alkalis, solvents and powerful reagents, such as fluorine gas, at temperatures of less than 60 C.

Our experiments with polythene were usually done on dogs. It should be mentioned, however, that lymph fistulas of the thoracic duct, liver and intestinal lymphatic vessels in rats have been made in our laboratory with polythene tube cannulas. Ether, or sometimes pentobarbital sodium, anesthesia and sterile surgical technic were used. The polythene was sterilized either by boiling in water for twenty minutes or by washing in alcohol-ether mixture followed by immersion for half an hour in 1 to 1,000 aqueous solution of benzalkonium chloride "zephiran chloride."

It is convenient to describe our results by grouping them according to the form of polythene used: commercially extruded tubing, film or tubes made by our technic of fusing layers of film into tubes.

EXTRUDED POLYTHENE TUBING (COMMERCIAL)

Our first uses of extruded polythene tubes were for cannulas in the lymphatic vessels of the liver and the thoracic duct.[1] Until recently the right sizes of polythene tubing, except for use as cannulas in lymphatic vessels of rats and occasionally in small lymphatic vessels of the liver in dogs, have not been available. The tubing we had for this study was either of capillary size or much too large for most lymphatic vessels of dogs. We have had to rely on a polyvinyl copolymer tubing for most of our lymphatic fistulas in dogs; although this tubing gradually became hard, we found it almost as satisfactory for purposes of lymph drainage as polythene. Suffice it to say that clotting of lymph within the tube, the phenomenon which heretofore has been the greatest single factor preventing continuous collecting of lymph, has never occurred primarily in our polyvinyl or polythene plastic can-

1. Cain, J. C.; Grindlay, J. H.; Bollman, J. L.; Flock, E. V., and Mann, F. C.: Lymph from Liver and Thoracic Duct: An Experimental Study, Surg., Gynec. & Obst. **85**:559-562 (Nov.) 1947. Grindlay, J. H.; Cain, J. C.; Bollman, J. L., and Flock, Eunice V.: Experimental Studies of Liver and Thoracic Duct Lymph, Minnesota Med. **31**:654-655 (June) 1948.

nulas. We have considerable pathologic evidence that the lymph clots which, temporarily at first and later permanently, block the plastic tubing arise in the lymphatic vessel itself, apparently from the intima adjacent to the tip of the tube. Frequently, lymph has flowed continuously until the dog became thin and relatively dehydrated from loss of lymph.

Polythene tubing has been of help in making fistulas of the common bile duct and of the pancreatic duct. We have never seen solid material adhering to the walls of, and blocking, tubes used for these

TABLE 1.—*Polythene Film to Replace Excised Dura, and Polythene Ventriculostomy Tubes*

Dog	Operation Performed with Polythene		Period Observed (Mo.)	Present Status
	Surgical Lesion	Use of Polythene		
1	Removed right temporoparietal dura	Film, to replace dura	2	Killed, 2 mo.
2	Removed right temporoparietal dura	Film, to replace dura	2	Killed, 2 mo.
3	Removed right temporoparietal dura	Film, to replace dura	6	Killed, 6 mo.
4	Removed right temporoparietal dura	Film, to replace dura	10.5	Alive and well
5	Removed right temporoparietal dura, plus laceration of brain	Film, to replace dura	4	Killed, 4 mo.
6	Ventriculostomy	Ventriculostomy tube	2	Killed, 2 mo.
7	Ventriculostomy	Ventriculostomy tube	12	Explored, 4 mo.; alive and well now
8	Ventriculostomy	Ventriculostomy tube	6	Killed, 6 mo.
Monkey				
1	Removed right temporoparietal dura	Film, to replace dura	12	Alive and well
2	Removed right parietal dura, plus laceration of brain	Film, to replace dura	6	Killed, 6 mo.

purposes; nor have we observed significant changes, dilatation or infection of the bile or pancreatic ducts proximal to the point of drainage.

Reports[2] from our laboratory have already been made on the use of polythene tubing for drainage of the lateral ventricles of the brain

2. Brown, M. H.; Grindlay, J. H., and Craig, W. McK.: Preliminary Report on Experimental and Clinical Studies with Polythene Film, Proc. Staff Meet., Mayo Clin. **22**:453-456 (Oct. 1) 1947; The Use of Polythene Film as a Dural Substitute: A Preliminary Report, J. Neurosurg. **4**:505-507 (Nov.) 1947; The Use of the Polythene Film as a Dural Substitute: An Experimental and Clinical Study, Surg., Gynec. & Obst. **86**:663-668 (June) 1948.

(table 1). Tubes with an internal diameter of 2 mm. were inserted through the dura and brain into the lateral ventricles of 3 dogs. The other end of the tube was inserted under the dura at a point remote from the site of ventriculostomy. All of these tubes functioned; the two tubes that were removed two and six months, respectively, later showed no signs of coating with organic material: 1 dog that has had a tube in place for one year is well and has never shown signs of abnormal behavior or of motor or sensory disturbance. An exploratory operation at four months showed the tube in this dog to be unobstructed and apparently causing no ill effects.

We have inserted polythene tubes through the left renal vein (after nephrectomy) into the inferior vena cava and through a splenic vein into the portal vein in dogs. After recovery of the animals from operation, venous pressures have been measured in these vessels by connecting the tubes to water manometers. The tubes have remained open for several days, even weeks, without treatment directed at altering coagulation or prothrombin time. Eventually, the plastic tube was blocked by a thrombus which originated in the vein through which the tube had been inserted and which had propagated down that vein to a point beyond the open tip of the tube, or which began as a small mural thrombus involving the wall of the vena cava or portal vein at the point where the tip of the tube appeared to impinge on the wall of the vein.

Polythene tubing of small diameter (1/40 inch [0.6 mm.]) was observed to have advantages over the usual intravenous needle for continuous intravenous therapy.[3] Tubing of this size can be introduced into a vein through a no. 17 gage intravenous needle. The tube is slipped some distance up the vein and the needle is withdrawn over the external end of the tube. Our first use of this method of giving continuous intravenous infusions was to replace lymph in dogs with thoracic duct fistula, which lost such quantities of lymph that intravenous replacement of lymph was necessary. The intravenous infusion was carried out over a period of several hours each day. During the night the tube was occluded with a short stylet. It was possible to give daily infusions through the same tube into the same vein for two weeks. When the vein and the tube were removed surgically, the wall of the vein was observed to be greatly thickened near the point where the tube entered the vein, but considerably less or only slightly thickened in the region near the tip of the tube.

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3. Guenther, T. A.; Grindlay, J. H., and Lundy, J. S.: New Flexible Capillary Tubing for Use in Venoclysis, Proc. Staff Meet., Mayo Clin. **22**:206-207 (May 14) 1947.

EXTRUDED POLYTHENE FILM (COMMERCIAL)

We have placed thin (1/500 inch [0.05 mm.]) sheets of polythene subcutaneously between muscle layers and intraperitoneally in dogs. No undesirable reaction was noticed in any case. When the film was removed from subcutaneous or fascial layers four weeks later, it was observed to be surrounded by a thin white layer of hyaline tissue containing few cells or vessels. A sheet of film, which was placed under a long laparotomy incision at the time of an anastomosis of the common duct in each of 2 dogs, was observed four weeks later to have prevented adhesions to the laparotomy wound and to have caused no reaction. There was no sign of thickening or increased vascularity of the omentum, and the peritoneal surfaces were smooth and glistening.

As part of our study with Dr. M. H. Brown and Dr. W. McK. Craig on possible neurosurgical uses of polythene, similar thin sheets of polythene (1/500 inch [0.05 mm.]) have been used in a series of 5 dogs and 2 monkeys (table 1) to replace surgically excised areas of dura mater.[2] Four dogs and 1 monkey have been killed under anesthesia at intervals of two to six months. One dog has now had its artificial dura in place for ten and a half months and 1 monkey for twelve months. Both surviving animals are well. In each case, all the dura covering the temporoparietal region was excised and the area was covered by a slightly larger piece of thin polythene film, held in place by a few silk sutures to the adjacent edge of the dura. At the time of this operation in 1 dog and 1 monkey, deep lacerations were made in the posterior parietal area of the same side. Although this lesion produced severe loss of sensorimotor function, recovery proceeded rapidly and was complete before the animals were killed under ether anesthesia, the dog at four months and the monkey at six months. These animals, as well as 2 dogs without lacerations killed at two months and 1 dog without laceration killed at six months, have not disclosed any evidence of cicatrix between membrane which formed under the film and pia mater or cortex.

At the two month interval, we observed that beneath the polythene film there was a semiopaque white membrane which could easily be peeled from the pia mater. A similar membrane was present on the other side of the film, loosely attached to the skull flap. Because exploration was performed just before the deaths of these animals, we could also observe that the act of peeling the membrane away did not produce bleeding, active or oozing, from the pia mater. The membranes of the dog killed at four months and the dog and monkey killed at six months were different only in that they were less thick than those of the animals killed at two months. From examination of the gross specimens one had the impression that the membrane under the film was continuous with normal dura at its border. Histologic

sections confirmed this impression. The membrane consisted of collagenous fibrils oriented in the same plane as the overlying film, having no connection with the underlying pia mater. Not even in the cases of the dog and the monkey that had lacerations of the pia mater and the brain in the area covered by film was there an association between the membrane and underlying cicatrix of pia mater and brain. The pia mater of all the animals examined was of normal thickness and had the usual number and size of vessels. Except in the immediate area where lacerations of the brain had been made, the surface of the brain appeared normal.

Our experimental studies with polythene film have led us to suggest several temporary uses for such film in clinical surgery. Thin perforated film has proved to be superior to petrolatum dressings on granulating wounds and ulcers; there is better drainage and, of course, no possibility of droplets of petrolatum inducing a foreign body reaction. Tissue drains, made of strips of film, and Penrose drains, made by rolling a tube of film, have proved to be superior to their counterparts of rubber. As a material to be placed against the raw surface of a perineal resection wound, polythene film is better and easier to use than other materials. When thin film is placed between subscapular tissues and the beds of resected ribs after the first stage of thoracoplasty, the second stage of the operation is made much easier because no scar has been formed between these structures.

MOLDED POLYTHENE TUBES

The absence of foreign body or inflammatory reaction on the part of tissues with which polythene was in contact encouraged us to attempt to make specially shaped tubes for the surgical reconstruction of various tubular organs and ducts.[4] Our experience with commercial polythene tubes in lymphatic vessels and blood vessels convinced us that thrombosis occurred not because of the material from which the tube was made but because the tip of the tube was a cause of trauma to the adjacent intima. In tubular structures other than blood vessels and lymphatic vessels, in which slight local injury to the inner wall of the structure would not initiate an entirely new phenomenon, such as thrombosis, we felt that polythene tubes might be used for permanent implantation.

Our first interest in such tubes was inspired by the knowledge that while vitallium and rubber tubes work satisfactorily within the reconstructed common bile duct for a time they eventually become

4. Grindlay, J. H.: Method of Making Tubes of Polyethylene Film for Use in Anastomosis of the Common Bile Duct, Trachea, and Pelvic Colon, Surgery **24**: 22-29 (July) 1948.

occluded with bile solids. In addition we observed that polythene, like paraffin, is not wetted by water and that it is difficult or impossible to cause oils, soaps, fibrin, mucus and other organic and inorganic solid or semisolid material to adhere or cohere to polythene. These facts suggested that bile solids might not occlude polythene tubes in the common duct.

There are several reasons that, so far, we have not found commercially extruded polythene tubing satisfactory for our purposes. It is extremely difficult to obtain tubing with the proper ratio of wall thickness and diameter from commercial sources. In order to make permanent alterations in shape or to mold polythene tabs, flanges or bands to commercial tubing, it is necessary to heat it to a temperature above its softening point. Polythene, like glass, contracts in all planes when it is soft. Because of this characteristic, commercial tubing becomes thick walled and has a narrower lumen after it is heated than before.

We learned, by the trial and error method, to mold polythene film into tubes.[4] The method consists in tightly wrapping layers of film, less than 1/200 inch (0.13 mm.) thick, about polished brass tubes. When the rolled film is held tightly wrapped and is heated sufficiently, the several layers of film fuse together and, although the mass shrinks tightly to the brass tube, the layers do not undergo longitudinal shrinkage. In order to be able to remove the polythene tube after it has been cooled, we coat the brass tube before the film is wrapped about it, first with a film of soap and then with two thicknesses of ordinary cellophane. The soap acts as a lubricant when the tube is removed from the brass form, and the cellophane is easily removed from the polythene tube. When we wish to make a tab on the side of the tube, we wrap a few layers of narrow film at the point where the tab is desired and, during the heat-fusing stage, pinch the band at some point with a broad-pointed hemostat. A band is made by wrapping layers of narrow strips of film at points along the tube where bands are desired. Flanges can be made in the same way, except that several layers of thick film (1/200 inch [0.13 mm.] or greater) are wound around the tube at the proper places. During the fusion process the strips of film curl up over the centrally placed ligature. At the end of the fusion process the ridges have a broad base, fused to the outer wall of the tube, and have a ligature buried in the midst of their mass.

In order that we may ascertain the position of tubes by roentgenographic examination, we have adopted the practice of placing tantalum wires between layers of film. When the tube is fused the tantalum wire becomes permanently embedded in the tube wall. A single wire with a diameter of 1/200 inch (0.13 mm.) so placed can be seen

clearly on a roentgenogram even when it is in a tube which has been placed in the common duct.

MOLDED TUBES FOR ANASTOMOSIS OF THE COMMON DUCT

We have used two sizes of common duct tubes; one has an internal diameter of 5 mm. and the other of 3 mm.; wall thickness is approximately 0.25 to 1.00 mm. Both of these tubes are 8 cm. long, and both, though rigid enough so that there is no danger of their collapse, are sufficiently flexible that they may be bent to a considerable degree during their insertion. If at operation the tubes were observed to be unnecessarily long, they were cut to the proper length with knife or scissors.

Three designs of tubes have been used in our experimental study, a study in which we have collaborated with Dr. Howard Gray. One, for end to end anastomosis, has a centrally placed tab and an internal diameter of 5 mm. Another, for anastomosis of the duct above a

TABLE 2.—*Anastomosis of Common Bile Duct With Polythene Tubes*

Dog	Weight of Dog (Kg.)			Observed Period (Mo.)	Procedure (Type)
	Original	With Duct Obstructed	Present		
9	13.0		21.2	15	2 cm. of duct removed; gap bridged with polythene tube
10	13.5		14.8	15	
11	12.0	11.2*	14.2	12	Anastomosis of duct, above stricture, to side of duodenum with polythene tube
12	16.6	15.6	19.2	11	
13	17.2	16.5*	18.4	11	
14	17.8	15.7	16.6	10	
15	15.2	13.2*	14.3	9	
16	20.5	19.3*	20.2	9	

*Dog was jaundiced

stricture to the duodenum or jejunum, has a 5 mm. lumen and has two flanges, about 1 cm. apart, at one end. We have also used 3 mm. internal diameter Mayo-Sullivan type tubes, the two bands being about 1 cm. wide and 1 cm. apart, for anastomosis of normal ducts or ducts with small lumens.

Two dogs (table 2) are alive and well fifteen months after resection of 2 cm. of the normal common duct. Continuity of the duct was reestablished by anastomosis over a piece of commercially extruded polythene tube 7 cm. long and having a wall thickness of 1 mm. and an internal diameter of 1.75 mm. Flanges at the ends of these tubes were made by heating the ends over a flame, the result being both an external lip and an unavoidable internal lip, the latter decreasing the lumen at each end of the tube to 1 mm. At the conclusion of the

anastomosis there was a gap of 1.4 cm. between the two ends of the duct bridged by tubing. The gap was covered by omentum which was sutured over the exposed tube. Both of these dogs have been in excellent health, have gained weight since operation and have had normal serum bilirubin levels. Laparotomy at one and a half and three months, respectively, has in each case disclosed a normal-appearing liver with a slightly dilated common bile duct (the gallbladder was removed at the first exploratory laparotomy) and a palpable polythene tube.

The tube was removed from 1 dog at fourteen and a half months and was observed to contain a mixture of mucus and black solid materials. Although this was easily removed by holding the tube beneath a water faucet, it was deemed that bile flowed not through but around the tube. We feel that the small diameter of the ends and the length of the tube were the causes of stasis of bile in this tube. The liver of this dog appeared normal, and the common duct was only slightly enlarged and thickened. The bile, which flowed freely from the opened duct, appeared to be entirely normal. After the tube had been removed, the opening in the lower end of the duct, through which the tube had been removed, was sutured with interrupted silk sutures to a small opening that was made in the upper part of the duodenum. Before these sutures were tied, a polythene Mayo-Sullivan tube (4.5 cm. long and having an internal diameter of 3 mm.) was inserted into the duct and duodenum. Since operation, the dog has remained well and has not had jaundice.

Strictures of the common duct were made at operation in a group of dogs (table 2) at the time when cholecystectomy was performed. Two to three months later an anastomosis was made with a polythene tube between the duct above the stricture and the side of the duodenum. At the time of this second operation, the dogs were losing weight and most of them were jaundiced. After anastomosis, the dogs recovered their appetites and their jaundice disappeared. Six such dogs have now been observed for from nine to twelve months. All have maintained their normal weights, have shown no signs of illness and have had normal serum bilirubin levels. The polythene tubes of 2 dogs were removed at twelve and seven months, respectively, for inspection. Although they were loosely coated with black-stained mucus, both tubes were unobstructed and in both dogs there was a free flow of normal-appearing bile from the common duct. The tubes were replaced after examination.

Some of our early attempts to employ polythene tubes for anastomosis of the common duct in dogs with experimental strictures were not successful. Three dogs lived only one to two months, dying of biliary obstruction because the tubes did not remain in the duct and a

new stricture formed. In these dogs the tubes were short pieces of commercially extruded tubing on which flanges or tabs of a size that would keep the tube in place could not be made. Our first molded polythene tubes were not satisfactory either. Three dogs were relieved of their obstruction and were well for one, two and three months, respectively, before signs of obstruction of the common duct again developed. Necropsy showed that the flanges of the tubes implanted in these dogs had separated from the shafts of the tubes; a flange remained, but the tube in each case had passed into the duodenum.

MOLDED TUBES FOR ANASTOMOSIS OF TRACHEA

The possibility that a portion of the trachea containing a tumor might be resected and continuity of the trachea might be established by means of a tube was suggested by Dr. Herman Moersch and Dr. O. T. Clagett. The dangers that such a tube would become occluded with adherent mucus or that mucus would accumulate behind the tube were hazards that we considered; these were the factors which had caused failure some years ago in our laboratory. The problem did not attract us until we had had some experience with polythene, had observed that it was nonirritating and that other materials did not adhere to it and had learned how to make molded tubes.

The external features of the tube that we use for anastomosis of the trachea are a raised ridge at each end and a central tab; the internal surface of the tube is smooth and glistening. The raised ridges at the ends of the tube were designed to expand the membrane between adjacent cartilaginous rings, thus making an internal air seal. Our original hypothesis was that we must make the anastomosis airtight by means other than by tying ligatures about the ends of the trachea over the tube. Such a method would seem to invoke the following chain of disastrous events: necrosis of the ends of the trachea beneath and beyond the ligatures, loosening or displacement of the tube, leakage of air and asphyxia or mediastinitis.

The operative technic of anastomosis of the trachea with this tube is simple and permits an anastomosis to be made quickly. The portion of trachea to be excised is freed by blunt and sharp dissection. An incision is made half through the trachea in the membrane between cartilaginous rings at the aboral end of this portion, and three silk traction sutures are placed around the ring of cartilage beyond the incision. A similar incision is made at the other end of the segment to be removed, and traction sutures are inserted. Next, a longitudinal incision is made through the portion of trachea to be removed, and the polythene tube is placed in the trachea through this opening. While appropriate traction and countertraction are made on the two

sets of traction sutures and while the tube is manipulated, the two ends of trachea are approximated over the tube. Opposite traction sutures are tied to each other, thus becoming three interrupted sutures, and one can leisurely proceed to place a few more end to end interrupted sutures, as well as to remove the segment of trachea by completing the upper and lower transverse incisions. One of the interrupted sutures

TABLE 3.—*Anastomosis of Trachea with Polythene Tube or Implantation of Tube in Trachea or Bronchus*

Dog	Operation Performed		Period Observed (Mo.)	Bronchoscopic Examination (Mo. Post-operatively)	Present Status
	Region	Segments Resected/ Implant			
17	Neck	8	7.5	1.5	Died, acute asphyxia from loose tube
18	Neck	5	7	1	
19	Neck	5	3	1	
20	Neck	4	10	1.5, 3, 7	Killed, for examination of trachea
21	Neck	3	1.5	1	
22	Neck	5	1.5	1.5	
23	Neck	6	11	1.5, 9	Tube removed 10 mo. postoperatively
24	Neck	5	2		Tube removed 1.5 mo. postoperatively
25	Neck	4	12	0.5, 2, 10	Alive and well
26	Neck	5	2		
27	Neck	5	2		
28	Neck	5	1		
29	Neck	5	1		
30	Thorax	4	9.5	1, 5, 9	Alive and well
31	Thorax	4	1		
32	Thorax	4	1		
33	Thorax	Implant	10	0.5, 4.5, 8.5	Alive and well
34	Thorax	Implant	9.5	4, 8	Tube removed 9 mo. postoperatively
35	Left bronchus	Implant	8.5	3, 7	Tube removed upper trachea, 7 mo. postoperatively
36	Right bronchus	Implant	8	2.5, 6.5	Tube absent 6.5 mo. postoperatively

is passed through the substance of the central tab of the tube. This suture holds the tube in place and prevents its rotation.

The foregoing procedure has required only the usual anesthetic apparatus for any intrathoracic procedure in dogs. One might anticipate that, if used in human patients, close team work between anesthetists, bronchoscopists and surgeons will be required. We have ob-

served that only about one minute is required between the time the trachea is opened and the traction sutures are tied.

Sixteen dogs in our series (table 3) have had from three to eight tracheal segments removed by this procedure (the usual total number of segments is thirty-five). Without exception the postoperative period has been completely uneventful, and no animals have died later except a few of the first dogs of the series in which the tube became loose and obstructed the trachea. Another 2 dogs have had tubes implanted in the trachea, without resection, and 2 dogs have had tubes implanted in the right or left main bronchus.

A segment of from three to eight cartilaginous rings of trachea (average of five) was removed from the lower cervical portion of the trachea of 13 dogs. Three of these dogs have died. One died at seven and a half months and another at seven months of acute asphyxia after the polythene tube had become loose and had lodged in an oblique position just below the larynx. In both dogs the cause of the tube coming loose was that the polythene ridges or flanges on the ends of the tube had separated from it. These dogs were among the first of our series, and at that time the method of making tubes was being developed. Another dog died suddenly at three months, because of partial collapse of the tube, which in this instance also was one of our early tubes. Granulation tissue had formed under the loose and partly collapsed tube and, at the caudal end of the tube, extended into the lumen of the trachea as a papilliform granuloma. Obstruction was caused by the granuloma acting as a ball valve in the flattened tube.

Another 3 of the 13 dogs that had undergone resection of the cervical portion of the trachea were killed, one at ten months and the other two at one and a half months. These dogs were in excellent condition and had no cough or other symptoms at the time they were killed.

The polythene tubes were removed from another 2 dogs, after they had been in place ten months and one and a half months, respectively. Removal was performed through tracheotomy incisions at the lower end of the tube. We wished to know whether a stricture would develop at the anastomosis after the tube had been removed. If further observation of these and other dogs teaches us that a stricture does not develop, it might be desirable to remove all anastomosis tubes after a certain interval, either through a low tracheotomy incision or, conceivably, through a bronchoscope. These 2 dogs have now been observed for two months since the tubes were removed; the dogs are well and bronchoscopic examination shows normal-appearing trachea at the former site of the tube.

The remaining 5 dogs that underwent resection of the cervical portion of the trachea have not had their anastomosis tubes removed.

One of these dogs has had its tube in place for one year and the others for only one to two months. All are well and have no detectable symptoms from the presence of the tube.

A segment of the thoracic portion of the trachea consisting of four rings was excised from each of 3 dogs. The operative exposure of the area was accomplished by a high right intercostal incision, division of the azygos vein and retraction of the right vagus nerve. The resected portion of trachea was only three or four rings above the coryna. One dog has been observed for nine and a half months since operation and the others for only one month. These dogs also are well and show no signs that the tubes are present.

We have tried to learn whether a polythene tube might be implanted in the trachea or a bronchus merely to provide an adequate airway. In clinical surgery such a tube might be useful in cases of unresectable stricture or tumor. The tube that we have used in dogs for this purpose is slightly different from an anastomosis tube. Instead of narrow and relatively high ridges at the ends of the tube, there are broad flat bands. Such bands make the tube easier to insert and provide it with enough rigidity to keep it from collapsing. Like an anastomosis tube, this tube has a centrally placed tab, so that it may be fixed with a suture to the trachea.

Two dogs have had such tubes implanted in the lower thoracic portion of the trachea; another has had a tube implanted in the right main bronchus, and another has had a tube implanted in the left main bronchus. The tube was discovered to be lodged in the trachea, just beyond the larynx, during bronchoscopic examination at seven months in the last dog and was removed bronchoscopically. Between bronchoscopic examinations at two and a half and six and a half months, the dog with a tube in the right main bronchus apparently coughed up its tube. A thorough search (at six and a half months) showed a normal bronchus and trachea, but no tube. The tracheal tube was removed surgically from 1 of the 2 dogs with tubes implanted in the lower part of the trachea after it had been in place for nine months; the other dog has had its tube for ten months. All 4 of these dogs have remained well and, even in the case of the dog with the tube lodged in the trachea behind the larynx, have not had cough.

Bronchoscopy has been performed on one or more occasions on all dogs, except those that underwent operation within the last two months, by Dr. Moersch and Dr. Schmidt (table 3). One observation, absence of retained secretion, has been uniform enough to be significant. The only time that an accumulation of mucus was observed was two weeks after resection of four cervical tracheal segments (dog 25). Subsequent bronchoscopic examinations of this dog at two months and ten months showed no retained mucus. Almost as significant an

observation has been the fact that usually it has been somewhat difficult to find the tube with the bronchoscope. For a time, in fact, we thought that epithelium had grown over the inside wall of the tube. When 1 dog (dog 22) was killed six weeks after operation, we learned that no tissue had grown over the inside of the tube. The reason for our doubt was that the tubes are transparent enough and cause so little reaction that they are inconspicuous. We have noted, however, that the upper end of the tube has become more easily seen the longer the tube has been in place.

Other bronchoscopic observations have also been normal. There has been no evidence of stricture at the site or neighborhood of a tube or at the former site of a tube after it has been removed. So far, we have observed no difference, clinically or by bronchoscopic examination, between dogs which have had the two ends of the trachea brought into close apposition over a tube and dogs (dogs 17, 18, 22, 23, 24 and 27) in which there was a gap of 1 to 2.5 cm. between the ends of the trachea after the anastomosis had been completed.

Pathologic studies of the trachea in this series of dogs concern dogs that had died as a result of a displaced tracheal tube, dogs in which a biopsy was made at the time of surgical removal of a tube and dogs killed at intervals of one and a half and ten months after tracheal anastomosis. Necropsy disclosed, in the 3 dogs which died, that the tubes had recently broken loose (dogs 17 and 18) or had partly collapsed (dog 19) and caused acute asphyxia. Except for acute edema of the larynx and upper part of the trachea in dogs 17 and 18 and the observation of pink frothy material in the tracheobronchial tract behind the obstruction, the only observations were in the tracheal wall adjacent to the tube or where it had been until it broke loose. Here there were two or three plaques of granulation tissue 1 to 2 cm. in diamter. The papilliform granuloma of dog 19 arose from one of these plaques. Biopsy of the trachea in the region of the anastomosis has not revealed any significant differences from normal trachea, merely slight increases of connective tissue, capillaries and lymphocytes. Two dogs were killed six weeks after tracheal anastomosis and 1 dog ten months after anastomosis. The proximal and distal portions of the trachea and the bronchi of these dogs appeared entirely normal, and there was no evidence of retained mucus. The epithelial surface of the tracheal wall surrounding the tube was marked by slight increase of fibrous tissue and a few lymphocytes; the epithelium itself appeared to be normal tracheal epithelium, except for a few small granulating areas where there were no epithelial cells.

Our pathologic studies in dogs 17, 18, 22, 23 and 24 provided us with an opportunity to learn whether cartilage formed in the wall of the trachea when a gap was left between the ends of trachea. Care-

fully made examinations have not revealed any cartilage in the fibrous tissue which formed over the tube to bridge the gap. However, the gap has always been appreciably shorter by measurement than it was at the time of anastomosis, probably because the fibrous tissue contracted as it became less vascular.

MOLDED TUBES FOR ANASTOMOSIS OF THE PELVIC PORTION OF THE COLON

The higher morbidity and somewhat higher mortality rate of anterior resection for carcinoma of the lower part of the sigmoid and upper part of the rectum suggested to Dr. John M. Waugh and to us that a leak-proof anterior anastomosis might be made better over a prosthetic tube rather than by the currently used open or closed suture technics. We conceived of a two piece tube, one part fitting into the other, which would be left in place until sufficient healing had occurred and would then be removed. Should the device be practical, we believed it possible that healing would progress more rapidly if the anastomosis were protected from the fecal stream and that, consequently, there would be less likelihood that a stricture would develop. The tube that we constructed had features in common with the Murphy button.

The unassembled tube consists of two pieces. One piece is a short tube and the other a long tube. The short tube is slightly larger in diameter than the long tube, just enough larger so that with slight force it will slip over the end of the longer tube. The model of this device for use in dogs has external ridges, several millimeters high and 2 cm. apart, at one end of each of the two tubes. The inside or longer tube is 7 cm. long, and the outside or shorter tube is 3.5 to 4 cm. long. To simulate the manner of fitting the tubes together, one introduces the ridgeless end of the long tube into the ridgeless end of the short tube and forcefully pushes the end of the long tube through the short tube.

At operation, the ridged ends of the two tubes are inserted into the open ends of the bowel, the long tube into the proximal end of the colon and the short tube into the rectum. Both tubes are inserted about 2.5 cm. into the bowel, a distance sufficient for both ridges to be in the bowel. A surgical gut purse-string suture, which has been placed previously at the edge of the bowel, is then drawn tight and tied. The two tubes are next, with slight force, fitted together. Continuity of the bowel is thus established. Further steps in the technic are to tie the surgical gut purse-string sutures of the two ends of bowel together and to place interrupted silk sutures around the anastomosis, approximating the serosa of the colon to pelvic or rectal peritoneum.

Our experimental study is based on a series of 6 large healthy female dogs. The dogs were fasted for the usual twenty-four hours be-

fore operation. No preoperative purgatives or enemas were used, and colostomy was not performed at the time of operation. After operation the dogs were given only water for one day, skim milk and dextrose for two days and the usual kennel ration thereafter. All of the dogs passed the polythene tubes, still fitted together as a unit, spontaneously during defecation. All of the dogs but 1, which passed its tube on the sixth postoperative day, passed their tubes on the seventh day. It should be noted that the surgical gut purse-string sutures, the only means by which the tubes were held in place, were no. 000 chromic surgical gut.

Proctoscopic and rectal examinations were made of this series of dogs at intervals of one, two, four, five, six, seven, ten, eleven and thirteen weeks by Dr. N. D. Smith. For the first four weeks some induration and slight narrowing were noted at the site of anastomosis. After four weeks the healed anastomosis could be palpated as a slight band, but there were no surrounding induration and no appreciable narrowing; proctoscopic examination confirmed the absence of stricture. Two dogs were killed, 1 dog at seven and the other at nine months after operation. Necropsy disclosed minimal pelvic adhesions and absence of retroperitoneal scar tissue. There was neither thickening nor narrowing of the bowel; in fact, it would have been difficult to mark the anastomosis had it not been for the interrupted black silk sutures in the intestinal wall.

COMMENT

This study is based on experiments which extend over an observation period of a few months to a little more than a year. Obviously because of the history of most foreign materials that have been tried for these and other purposes, it is necessary that larger and longer experience be had before a conclusive report can be given. These experiments, however, indicate that a representative variety of tissues and organs tolerate the presence of polythene, that polythene undergoes no change when buried in living tissue or body fluids and that polythene materials do not seriously impede the usual functions of some organs when they are used to restore anatomic continuity of those organs.

The experimental use of film in the peritoneal cavity has demonstrated that it causes little, if any, reaction. It is possible that in patients requiring operation for lysis of extensive peritoneal adhesions, a layer of film could be sutured over the principal deperitonized areas and left in place until serosa had grown in underneath the film.

Our experience with polythene tubes in lymphatic vessels and blood vessels leads us to believe that polythene tubes will function only temporarily to restore continuity of peripheral blood vessels. We

think that polythene tubes, however flexible, will cause trauma to adjacent intima and that, because they will always tend to cause turbulent flow of blood in peripheral vessels, thrombosis in the neighborhood of a tube will eventually occur.

Thin polythene film appears from our experiments to be superior to all other present materials for patching defects in dura mater. The film does not cause any detectable reaction, and the thin layer of tissue resembling normal dura which forms about the film does not become adherent to underlying tissues. Ventriculostomy tubes of polythene cause minimal reaction by brain tissue and have not become occluded. Whether, in cases of internal hydrocephalus, such tubes will function and relieve pressure remains to be determined.

Concerning molded polythene tubes we do not feel that our present method is necessarily the best. However, we have found the method simple, and it has allowed us to make alterations in size and design of tubes freely.

The experimental study on anastomosis of the common bile duct with polythene tubes is encouraging in that tubes have not become occluded in our experience of a little more than a year. In our few cases of recurrence of biliary obstruction, the obstruction has been caused, not by tubes, but by defects in the first tubes we made, which allowed the tubes to come apart and pass into the bowel. In our experience, also, a tube is more likely to function if it is of larger rather than of small diameter.

The most significant result of our experiments on anastomosis of the trachea with polythene tubes is that these tubes do not appear to obstruct the normal outflow of mucus. Up to the present, the only disasters related to the presence of the tube were in dogs that had acute obstruction of the trachea because a tube became loose and lodged obliquely behind the larynx or partly collapsed and allowed a granuloma to act as a ball-valve obstruction. These disasters and the fact that, by bronchoscopic examination, the tubes seem to fit more loosely the longer they have been in place have suggested to us that perhaps the tubes should be removed after complete healing of the anastomosis has occurred.

Our few experiments on implantation of polythene tubes in the trachea or main bronchi indicate only that the tubes cause little reaction. The underlying disease, stricture or unresectable tumor for which such a tube was to be used clinically, would probably be a more important factor in the success of the operation than the tube itself.

The experiments on the use of a two piece polythene tube for anastomosis of the lower part of the colon indicate that healing of the anastomosis occurs early, that the tube protects against leakage and that later stricture does not develop. An incidental observation was

that the tube made the technical part of the anastomosis easy; one could place the outer row of sutures easily because the tube within acted as a darning egg.

SUMMARY

Polythene (polyethylene), a polymer of ethylene and a flexible plastic substance, appears to be well tolerated by living tissue.

Extruded polythene tubes of small diameter have been used with success as cannulas in blood vessels and lymphatic vessels. Blood and lymph do not readily clot in these tubes.

Polythene film has been used to replace surgically excised dura and polythene tubes have been used for ventriculostomy tubes in dogs and monkeys. No undesirable reaction has occurred and no ill effects have been noted during an observation period of one year.

Molded polythene tubes have been used for anastomosis of the normal and obstructed common duct in a series of dogs. During the period of a little more than a year that some tubes have remained in place the dogs have had no signs of obstruction of the common duct and the tubes have shown no signs of becoming occluded.

Molded polythene tubes have been used for anastomosis after resection of a segment of trachea and for implantation in the normal trachea and main bronchi in a series of dogs. No significant local reaction and no retention of secretion caudal to these tubes has been observed, even in dogs that have now had such tubes for one year.

Two piece molded polythene tubes have been used in a series of dogs for anastomosis after resection of the lower part of the colon. Tubes have been passed, during defecation, in about a week. Leakage at the anastomosis and stricture of the bowel have not occurred.

DISCUSSION

DR. FRANK C. MANN, Rochester, Minn.: My only part in this investigation has been that of a scientific agnostic.

I have felt that the use of foreign material for reconstructive purposes in living tissue was a sign of surgical defeat. On the other hand, in our experimental work my colleague and I find places, conditions and experimental setups when it is necessary to use some mechanical device in order to accomplish the purposes of the investigation.

For many years we have used all of the different substances that have been recommended for reconstruction of tissue and have been disappointed in their use for our experimental work. This substance, polythene (polyethylene), which Dr. Grindlay mentioned, has been the most promising of any that we have used. I think that its favorable characteristics are: (1) Its surface does not wet, and (2) it causes little tissue reaction.

So far as our experimental work is concerned, it has proved to be of great value. Whether or not it can be adapted satisfactorily to clinical work will depend on the surgeons. As far as we are concerned, we are fairly well satisfied with its use.

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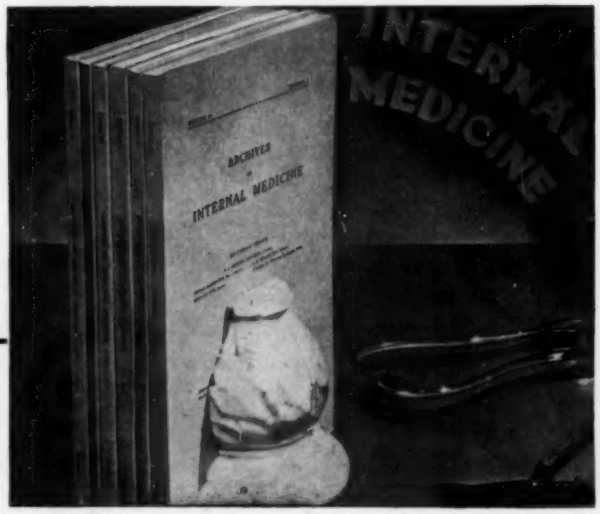

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